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Columbia University in the City of New York

LAMONT GEOLOGICAL OBSERVATORY

PALISADES, NEW YORK

CARIBBEAN CURRENT MEASUREMENTS, JULY 1964

Report prepared by: Robert Gerard

Technical Report No. CU-14-64 to the Atomic Energy Commission
Contract AT(30-1)2663

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The present report covers the period between 2 July and 16 July 1964, during which time the Research Vessel CONRAD made current measurement observations and performed other oceanographic work in the Caribbean island arc area.

Cruise Narrative, 2 July to 16 July 1964

The following members of the scientific party were aboard for this period:

S. Cory	- Hydro, current measurements	D. McNichol	- Coring
R. Sexton	- Hydro, current measurements	P. Sheridan	- Coring
M. Salkind	- Current measurements	D. Tolderlund	- Biology
E. Bonebakker	- Geochemistry	G. Carpenter	- Seismic
B. Turner	- Sound velocity	M. Truchan	- Seismic
M. Grady	- Electronics	A. Rice	- Seismic
J. Hubertz	- Magnetics	P. Rabinowitz	- Gravity

R. Gerard - Chief Scientist

2 July - Departed San Juan at 0300 after receiving freight shipment at midnight. 0900 loaded explosives at Roosevelt Roads and departed at 1000 after welding to deck a newly delivered hose reel winch. Took course south and east at the latitude of St. Croix so as to cross the inner Virgin Island sill. Radar positions plotted at fifteen minute intervals in order to tie in the topography. Considerable machine work being done to hook up the deep-pumping equipment and the current measurement instruments.

4 July - Ran southeast inside the island arc during the night, using sparker profiling equipment. Stopped for core in basin east of the Avies Ridge. Core indicated mostly sand, some flow-in. Arrived late in the evening at Dominica Channel. Proceeded to do a topographic survey, using Dominica and Martinique coastal points for radar targets. Considerable time spent in checking out current meters into Sanborn laboratory recorder,

also working on surface spar-buoy mounted current meter.

5 July - Continued running topographic survey. In the afternoon an emergency stop was made at the Island of Dominica in order to take a sick seaman to hospital. Back on position at midnight at the outer sill, anchored by 0700 on the 6th.

6 July - On anchor in 600 fathoms of water. Took bottom photographic current meter in the early morning. Film shows small current. Will repeat again with vanes having lighter weights. Took deck-lowered current meter profile, recording down and up in the afternoon. Also put over surface current meter to make hourly observations. This meter was drifted 500 feet downstream from the ship to avoid magnetic influence. Made preliminary experiment with sound velocimeter in the afternoon. Made Hytech In Situ hydro lowering with five Nansen bottles. Equipment working according to specifications. Recordings made both down and up.

7 July - Made another down and up deck-lowered current meter profile in the early morning. Had to repair broken bearing on the direction vane of the current meter. At 0800 a station was taken with the sound velocimeter. All equipment working well. Improved the Hytech In Situ rig by attaching a 300-lb. lead weight beneath for more vertical lowering. Set a surface drogue from anchored position and followed its course for approximately ten hours. Anchor holding fine, using two 500-lb. cubes plus a 300-lb. Danforth anchor. Maximum tension 2000 to 3000 lbs. Currents very mild. Station position 15°21.85'N by 61°04.0'W. Took another bottom camera current meter lowering, using lighter vanes to reflect smaller currents. Made another deck-lowered current meter lowering down and up and continued following drogue through several tidal oscillations. Another lowering was made with the Hytech T/D/S

instrument in the evening, and a time-series measurement extending over ten hours was made with the instrument recording at the depth just below the salinity maximum (140 meters). The signals from the three sensors were recorded one at a time on a frequency counter and print-out apparatus.

8 July - Got off anchor at 0430 and moved to a point about mid-way between Martinique and Dominica, depth 1000 fathoms, location 15°05'N by 61°14'W. Took plankton tow and a short gravity core to check the bottom while anchoring. After anchoring, put down sound velocimeter, Thorndike bottom camera current meter, and set a surface parachute drogue. Surface current meter array was set out with some improvements for making quieter record at 1500. Much less noise in the direction record while using a damping plate at about fifty feet beneath the surface current meter. At 1600 to 1800 made a Hytech T/D/S lowering with four Nansen bottles, noticing many temperature inversions which correspond to sound velocity changes of slope or direction.

9 July - Finished with deck-lowered meter at 0800. Put down sound velocimeter and made test of large multiplankton net. Got anchor up in early afternoon and proceeded to put over three deep drogues, #1 at 55 fms., #2 at 205 fms., and #3 at 547 fms. The deepest drogue had a pressure-versus-time recorder to indicate the depth during the experiment. All equipment in the water by 1700. Plotted drogue positions for several hours and then steamed westward to a shoal region on the Atlantic side of the central channel to take a core in 40 fms. Used a ten-foot length of pipe with a stepped surface cutting edge. Got nearly two meters of core with considerable shell fragments and watery material on the top, but with a firm compacted calcareous plug at the bottom of the core, cut out of a solid formation which stopped the pene-

tration. Bottom sample being preserved separately for possible radiocarbon determinations.

10 July - Returned to drifting buoys about 0100 and continued plotting positions. All moving west at a good rate. Seas rough during this period, making radar return very noisy.

11 July - Began picking up drogues at 0500, completing the job by late morning and returning then to Dominica to pick up seaman who was put ashore earlier. Interesting record obtained from drogue #3, indicating stable depth during entire period of observation and providing a good measurement of descent rate of the parachute in the open position. Took a Hytech T/D/S lowering on the Caribbean side of the channel in about 1000 fms. depth and then proceeded to the St. Lucia Channel to the south.

12 July - Anchored ship at 0200. Made In Situ T/D/S lowering with three Nansen bottles for control. Following this a bottom camera current meter station was made and then a lowering of the deck-recording current meter with a trace both down and up. Surface current meter was put out with a further modification incorporating a small pilot parachute to improve its quietness. Sound velocity meter was lowered, followed by another In Situ T/D/S and another deck-recording current meter lowering. Various surface plankton samples were taken, and one lowering of the large multiple net was made. Anchor station was completed by 2100. This location was 14°17.7'N by 60°54.9'W.

13 July - We ran north outside the island arc on a profiling seismic run, shooting half-pound blocks at one minute intervals. The attempt is being made to cover a portion of the Puerto Rico Trench extension to the southeast. During this run work was done on the coring winch and current

meters.

14 July - At 1145 crossed a narrow flat-bottom trough, five miles across at the bottom, which is believed to be an extension of a trench plotted farther north. The depth here is 3500 fms. An alteration of course was made to return to the feature for a piston core. At this same station a test was made on the deep-pumping apparatus and hose reel. All equipment functioned well, allowing six to seven gallons per minute while raising or lowering from the powered hose cable drum to a maximum of 500 feet. A test was also made on a transponding pinger for use with the bathyscaphe ARCHIMEDE, but tests were inconclusive because of the noise from the strumming of the core wire, which triggered the transponder at random intervals. Core #135 showed a penetration of 22 feet. Tested new plankton net attachment at this station with good results.

15 July - Reached Anegada Passage at 0700. After a brief topographic survey, anchored ship at 1030 in a strong current south of Virgin Gorda. The position of Anchor Station #4 is 18°22'N by 64°16'W. Put down Thorndike camera current meter, followed by the deck-lowered current meter. Put out surface current meter from the forward part of the ship and find that various improvements have reduced the noise of this record measurably. Set out surface drogue from anchored position and followed with radar. Minor repairs were required on the current meter rotor, but soon fixed by replacing the bearing pivot. Lowerings were made to 850 fms. At 1830 the sound velocimeter was put down, and some trouble was experienced in keeping the wire away from the ship's side due to swinging on anchor. At 2100 a lowering was made with the In Situ T/D/S with two Nansen bottles. At 2130 the surface meter was retrieved, and the anchor was hauled up at 0100.

16 July - Arrived San Juan at 1100.

Parachute Drogue Measurements

Table I is a summary of the stations made for current measurement and other related hydrographic observations. Figure 1 shows the anchored station locations indicated in this table.

During this short cruise, four surface and three subsurface parachute drogue current measurements were made. Figure 3 illustrates the surface parachute drogue assembly. The only modification of previous surface parachute drogue assemblies is that of the pick-up line, which facilitates bringing aboard the equipment without damage at the ship's side. Experiments made later in the summer with an identical assembly indicate that the surface drogue and buoy faithfully reflect the surface water movement. Fluorescein dye was placed around the surface buoy and five hours later, when the buoy was picked up, it remained in the center of the fluorescein dye patch, which had elongated and diffused considerably during this period but was still observable.

Subsurface drogue parachute measurements were made at three locations coinciding with the anchor stations shown in Figure 1. The subsurface parachute drogue assembly employed in these measurements is illustrated in Figure 2. The wire used to connect the parachute to the surface float was 3/32" diameter galvanized steel wire rope or 1/8" diameter galvanized steel wire rope. Surface floats were two-foot cubes of styrofoam (Danco Corp.) with a positive buoyancy of approximately 450 lbs. The parachutes were surplus personnel parachutes classified as 28-foot diameter. The assembly was similar in most respects to that described by Volkmann, Knauss and Vine (1956), except for

the use of ball-bearing swivels at the terminations of the wire rope and a "weak link" lanyard connection between the lower portion of the wire rope and the parachute. In all cases 200 lbs. of cast-iron ballast was used at the lower end of the assembly and a T-bridle was used to connect the various components near the lower end and to facilitate placing this portion of the assembly in the water without entanglement. The system for launching was the standard procedure of buoy first, paying out the wire, which was cut exactly to the depth where the measurement was required, at which point attachment was made to the T-bridle and parachute and weight portions of the assembly. The parachute was placed in the water as the final part of the assembly in an open condition and allowed to settle fully open.

Pressure-versus-time depth recorders were employed in several of these experiments in order to establish the descent rate of such an assembly with the parachute open and to monitor the depth of the parachute during the period of observation. At the end of the measurement, anywhere from twelve hours to several days after launching, the assembly was recovered with the exception of the parachute itself, and the depth record was examined to study the time-depth relationship. Disengagement of the parachute was accomplished by hauling in on the wire rope and thereby breaking loose the parachute by means of the "weak link" lanyard, consisting of 1/4" Manila rope by which the parachute was attached to the underwater assembly. After the parachute was disengaged, hauling on the wire rope was an easy matter over a capstan or a small winch.

Figure 4 is a copy of a depth-versus-time record for a drogue measurement in the Dominica Passage in the Caribbean. This assembly used 200 lbs. of iron ballast below the parachute, and it is observed that the parachute settled in the open attitude from the surface to 1000 meters (the exact

length of wire rope) in 100 minutes. The record shows that the parachute drogue remained at the depth of 1000 meters for approximately 39 hours, at which time the recorder and underwater assembly were recovered. Close examination of the record shows a slight displacement of center of the polar chart, resulting in a slightly eccentric circle traced by the recorder stylus. A relative displacement of the depth trace of approximately forty meters among the three twelve-hour cycles is observed in the record. The full scale of this recorder is 2500 meters. The manufacturer of the depth recorder, Benthos Co., states the accuracy of this instrument to be "plus or minus 2% of full scale".

It may be concluded that in this experiment the parachute remained at a depth closely approximating the length of the suspending wire throughout the thirty-nine hours of measurement. Additional measurements here and in the Gulf of Guinea, made with similar equipment, indicate the same performance.

<u>In Situ Temperature/Depth/Salinity (T/D/S) Recorder</u>

During this cruise the new Hytech T/D/S sensor and recording system was used for the first time on the R/V CONRAD. The performance of this equipment appears to be satisfactory and in line with the manufacturer's specifications. A total of fifteen stations were taken in the Puerto Rico Trench area and in the Caribbean between June and August 1964. During this particular period of the cruise, stations were taken as indicated in Table I in the principal passages, where anchored station measurements were made. Figure 5 shows an actual record made by the X-Y recorder down to 1350 meters depth in the Puerto Rico Trench area. The details of the thermal and salinity structure
out
are well brought/in this record, showing a maximum salinity at a depth of

about 130 meters, a minimum at approximately 750 meters, and a number of curious changes of slope and direction of the trace of temperature in the region between 750 and 900 meters. The additional markings on the record indicate reversing thermometer and salinometer measurements of samples collected by Nansen bottle on the same wire. Although the salinity and temperature scales are not indicated on the record, the independent values of salinity and temperature are comparable to the recorded data within the stated limits of the error of this device, temperature $\pm.05^{\circ}C$ and salinity $\pm.03$ o/oo.

In the Caribbean passages the records obtained with the In Situ T/D/S equipment are of great value in determining the levels of maxima and minima in temperature and salinity profiles for use in core analyses. Figure 6 shows an actual record taken at Anchor Station #1 in the Outer Dominica Passage and reveals the extreme nature of the salinity maximum at approximately 100 meters. A depth scale has been drawn in on this record, together with notations at particular times during the lowering, indicating wire-out as recorded from the meter wheel. It is apparent from this record and others that the salinity trace is characterized by a greater amount of noise, or "hunting", on the recorder under most conditions. This appears to be due to influences on the conductivity path caused by the presence of other components in the underwater package, and possible differences in response time of the various sensors which generate the salinity signal, i.e. the temperature compensation sensor and the pressure compensation sensor, together with the toroid coil for conductivity measurement. Careful examination of the record shows that some of the extreme excursions in the salinity signal correspond directly with spikes in the temperature record, which are real and repeatable both on lowering and raising the instrument at particular levels.

Of considerable interest was a time-series measurement and recording of salinity and temperature over approximately nine hours at Anchor Station #1. The level chosen for this measurement was at approximately 150 meters, just below the peak of the salinity maximum at this station. Figures 7 and 8 show these values plotted against time. The base line shown throughout these plots is the same for both salinity and temperature, but the actual conversion to absolute values is not indicated. The relative scale for the salinity and temperature appears on the left margin. One feature of this time-series plot shows that the salinity record remains "noisier" than the temperature trace, even though the instrument is not moving vertically through the water. Temperature and salinity are not recorded simultaneously as there was only a single-channel frequency counter available for these measurements. From about the first hour on 7 July, a decrease in both salinity and temperature is observed throughout most of the record, with a recovery towards the original values observed (Figure 8) during the last hour of measurement. If this is part of a cyclical variation, it would appear to have a period of approximately six hours. A maximum change in temperature of 1.5 degrees and a maximum change in salinity of .17 o/oo is observed. If we refer to the slope of temperature and salinity in Figure 6 in this depth zone, we find that these variations of temperature and salinity correspond to a depth difference of approximately thirty meters. This suggests that a wave with an amplitude of fifteen meters could account for the time variation observed in the salinity and temperature record. The depth unit appears to be quite stable as to its frequency output over the period of time of this station. Table II represents a copy of the frequency meter print-out for two periods of measurement: 2230 on 7 July and 0345 on 8 July. A maximum of 0.3 cycles appears to

be the instrument variation over his period. This corresponds to approximately 0.5 meters depth variation and may, in fact, be real due to small changes in wire angle during this time.

In order that the three channels of information (temperature, salinity, and depth) be recorded in a way which permits easy data handling, a punched tape data collection and storage system is proposed. Although the manufacturer has provided several proposals for data handling, the lowest priced system of $35,000 appears to be too costly and perhaps premature, as it is not known to what extent these observations may be treated as bona fide hydrographic station data. As this is the case, a punched-tape system has been proposed and priced by Lamont Observatory. The total cost for this system, as shown in Figure 13, is less than $7,000. This equipment is presently being procured under a National Science Foundation contract.

Sound Velocity Profiles

At each of the anchored stations indicated in Figure 1, sound velocity measurements were taken in the vertical column between the surface and the bottom. These measurements were made using two ACF sound velocimeters, together with a temperature and pressure transducer. It is of considerable interest to compare the nearly continuous records obtained from the sound velocimeters and the continuous temperature and salinity measurements taken with the Hytech T/D/S instrument. At Anchor Station #3 in the St. Lucia Passage, the temperature and salinity profiles, Figures 9 and 10, were obtained with the In Situ instrument. At this station (#13) the recorder was connected differently, while bringing the instrument from its maximum depth back to the surface, so that a record of temperature-versus-salinity (a T/S

diagram) could be drawn. A tracing of this chart record is shown in Figure 11. This record bears a close resemblance to a standard T/S diagram for this area, when the small scale oscillations of this record are smoothed.

A curious inversion of temperature at the bottom in Figure 9 may be compared with the traces of sound velocity shown in Figure 12 at this depth. This curious reversal of slope in sound velocity can be seen at approximately this depth in a number of stations taken eastward of the St. Lucia Passage in the Atlantic and may indicate a bottom outflow of water from the Caribbean to the Atlantic at the sill depth. It is noteworthy that this inversion is more apparent in the sound velocity records than in those of either temperature or salinity and suggests that sound velocity records may be examined for indications of subsurface currents.

Several bottom camera current meter observations were taken in 1964 in the St. Lucia Passage, indicating a current of low velocity at the bottom which flows outward from the Caribbean toward the Atlantic. These records, which verify the sound velocity findings, are presently being analyzed and compared with long-period recording current meter records taken in the same location in 1963.

Current Meter Observations

At each of the four anchor stations indicated in Table I, current meter lowerings were made from the ship's deck to the bottom. Each station represents recording of current at closely spaced depth intervals, both while lowering and raising the instrument. The current meter used for these observations was the Braincon electric current meter. This instrument is shown in Figure 14, together with a 500-lb. lead weight used to keep the conducting

hydrographic wire in a nearly vertical attitude in spite of strong currents. Also shown in this figure is an electrical swivel which connects the instrument, electrically and physically, to the terminus of the conducting hydrographic wire.

One feature of the deck-lowered current meter is that its magnetic compass is greatly affected by the proximity of the ship. As a consequence, direction readings, when the instrument is within several hundred feet of the ship, are questionable. To overcome this disadvantage in measuring surface currents, a surface current meter, drifted out from the ship on a 500-foot length of cable, was used. The meter, manufactured by Hydro Products Corp., is similar in operation to the deck-lowered meter already described.

At Anchor Station #1 the surface meter was put out from the bow of the ship, utilizing 500 feet of electric cable supported at the surface by plastic floats. The meter itself was suspended from a string of similar closely-spaced floats, each having a buoyancy of approximately four pounds. The weight of the meter in water was such that approximately three-quarters of this string of twenty floats was submerged, with a couple of floats submerging or reappearing as waves of several feet in height moved by. This configuration suffered from the fact that the string of floats would become entangled and would tend to behave as a large single float, rather than as a linear package where individual floats would contribute their buoyancy one at a time. Figure 15 illustrates the record obtained at this station. It will be noted that rather large excursions appear on the direction trace, amounting to extremes of nearly 90 degrees in direction.

At Anchor Station #2 a damper plate, consisting of an 18"-diameter aluminum disk, was added beneath the meter on approximately fifty feet of synthetic

rope. An improvement in the stability of the direction trace, showing extremes of no more than 30 to 40 degrees was the result. However, some clustering was still observed in the behavior of the surface float.

At Anchor Station #3 a small pilot parachute, of the type used to pull out a main parachute, was employed at the down-stream end of the string of floats. This is a 2 1/2-foot diameter parachute when fully deployed; and half of the panels (alternate panels) were cut out, reducing the effective surface area of this small drogue. Figure 17 shows the improvement in the "noise" of this record as compared to that of Stations #1 and #2.

Figure 18 is a schematic drawing of this system as it was eventually used. This technique is believed to be a useful contribution in providing a "quiet" surface current meter. Many installations of anchored buoy current meter arrays call for the use of subsurface floats to cut out the high frequency noise that has affected the subsurface buoys. However, in most of these configurations no provision is made for obtaining a quiet surface record. The use of a system such as described here may contribute toward the collection of noise-free surface measurements when used with a small auxiliary float at such stations.

Bottom Photographic Current Meter

During this cruise five stations were made in the Caribbean passages using the Thorndike bottom photographic current meter. This instrument, which is a modification of the Lamont underwater camera, is designed to be placed for short periods of time on the ocean bottom, at which time it automatically takes photographic frames of a compass, a direction vane, and three light-weight pendula set at 120-degree axes. These current sensing pendula

may be weighted so as to adjust the range and sensitivity for low velocity or high velocity currents. This instrument is one of the most reliable devices available for precise near-bottom current measurements for short periods of time at depths of one meter above the ocean bottom. Figure 19 shows the bottom photographic current meter in its tripod frame being prepared for a lowering. Figure 20 shows a photographic frame taken with the current meter camera. The compass is seen in the lower portion of the photograph, the direction vane in the center left, and the three current indicating pendula around the borders. Pendulum deflections are read from the white reference line on the base plate or from a second line in the photograph, which is that of the heavily weighted pendulum indicating tilt of the platform; the third white line is that of the current measuring pendulum. The instrument has been modified recently so that a portion of each frame includes a photograph of the ocean bottom. This will be useful in correlating measured currents with possible bottom sediment indicators of current, such as ripple marks.

Figure 21 shows three tow-tank calibration curves for this current meter, measured with various weights on the pendula. From this curve it may be assumed that this meter is useful down to velocities as low as 2.5 centimeters per second (0.05 knot).

Deep-Pumping Experiments

During the Caribbean cruise several experiments were made using a newly installed deep-pumping system. This equipment has been designed to bring up water samples from any depth down to 500 feet, and below that depth in 1000-foot increments extending to perhaps 10,000 feet. This pumping system utilizes a submersible turbine-type well pump attached to a hose-cable which is

contained on an electrically driven drum. The hose connection at the drum terminates at a rotary coupling, and the electrical connection to drive the pump is provided through a slip-ring assembly. The rig is designed to be used together with the 1/2" trawl and coring wire and winch. The pump and hose-cable are loosely attached to the core wire at twenty-foot intervals and lowered in unison with the core wire down to a maximum of 500 feet. The pump may collect a sample at any depth down to this level. Below 500 feet, 1000-foot sections of polyethylene tubing are added, so that with successive additions of tubing lengths, samples may be brought up from great depths. Operating the pump at fifteen atmospheres pressure reduces the tendency to cavitate while pulling against the frictional resistance of a great length of tubing attached below. Although no deep tests were made with the tubing sections attached, the pump itself was operated down to depths of 250 feet. At this depth the delivery of seven gallons per minute was measured through 500 feet of hose, half of which was coiled on the hose reel. The hose reel is shown in the top portion of Figure 22. The lower portion of this figure shows the submersible pump enclosed in a heavy pipe housing. Experiments are continuing on the present cruise of the R/V CONRAD with this pumping equipment, and it is hoped that samples will be taken for continuous processing in 1000-gallon volumes for radiochemical analysis of carbon-14, strontium-90 and cesium-137.

TABLES AND FIGURES

Tables

I. Summary of CONRAD 8 Stations

II. Depth Record, Station #C-8-8a

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1. CONRAD 8 Anchored Station Positions

2. Subsurface Parachute Drogue Assembly

3. Surface Parachute Drogue Assembly

4. Benthos Depth-versus-Time Record

5. Hytech In Situ T/D/S Record #III in Puerto Rico Trench Area

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7.) 8.) Salinity and Temperature-versus-Time Plottings, Anchor Station #1

9. T/D Diagram, Hytech Recorder, St. Lucia Passage

10. S/D Diagram, Hytech Recorder, St. Lucia Passage

11. T/S Diagram, Hytech Recorder, St. Lucia Passage

12. Sound Velocity Profile 37/2, St. Lucia Passage

13. Proposed Shipboard Data Storage System for Hytech In Situ T/D/S System

14. Braincon Deck-lowered Current Meter

15. Segment of Surface Current Meter Record, Anchor Station #1

16. Segment of Surface Current Meter Record, Anchor Station #2

17. Segment of Surface Current Meter Record, Anchor Station #3

18. Schematic Drawing of Ship and Current Meter System

19. Thorndike Bottom Photographic Current Meter

20. Photographic Frame taken by Thorndike Bottom Photographic Current Meter

21. Calibration Curves for Thorndike Bottom Photographic Current Meter

22. Top: Hose Reel Photograph
Bottom: Photograph of Submersible Pump

TABLE I

Station Summary Sheet -

Date	Current Meter Station	Position Lat.	Long.	Anchor Station	No. of Lowerings	Maximum Depth of Lowering (meters)
July 6	x	15°22'N	61°04'W	# 1	1	1050
July 7	x	"	"	# 1	2	1050
July 8		15°05'N	61°14'W	# 2		
July 8-9	x	"	"	# 2	2	2000
July 9-11		"	"	# 2		
July 11		15°05'N	61°21'W			
		14°56'N	61°18'W			
July 12	x	14°18'N	60°55'W	# 3	2	990
July 15	x	18°22'N	64°16'W	# 4	1	1740

TABLE I

R/V CONRAD 8, Summer 1964

Surface Drogue	Hours Obs.	Depth (m) Subsurface Drogue	Hours Obs.	Surface Current Meter	Thorndike Bottom Current Meter	Sound Veloci-meter	In Situ Hydro Station
				#1	#1		#8
#1	12				#2	35/1-2	#8a(t.s.)
#2	9				#3	36/1-1a	#9
				#2		36/2-3	
		#1 - 100	6.5				
		#2 - 350	39				
		#3 - 1000	39				
							#10
							#11
#3	8.5			#3	#4	37/1-2-3	#12,13
#4	6.5			#4	#5	38/1-2	#14

TABLE II

Depth Record, Station #C-8-8a
as indicated on frequency counter print-out

July 7, 1964		July 8, 1964	
Time	Frequency cycles	Time	Frequency cycles
2231	9797.7	0345	9797.5
2230	9797.7	0345	9797.5
2230	9797.7	0345	9797.5
2230	9797.8	0344	9797.5
2229	9797.7	0344	9797.6
2229	9797.8	0344	9797.5
2229	9797.7	0343	9797.5
2228	9797.7	0343	9797.5
2228	9797.8	0343	9797.5
2228	9797.8	0342	9797.5
2227	9797.7	0342	9797.5
2227	9797.7		
2227	9797.8		
2226	9797.7		
2226	9797.7		
2226	9797.7		
2225	9797.7		
2225	9797.7		
2225	9797.8		
2224	9797.8		
2224	9797.7		
2224	9797.8		
2223	9797.8		

Wire-out by meter wheel = 150 meters

Frequency		Depth
9797.0	=	140 meters
9798.0	=	145 meters

Depth Sensor Accuracy ± 7.5 meters

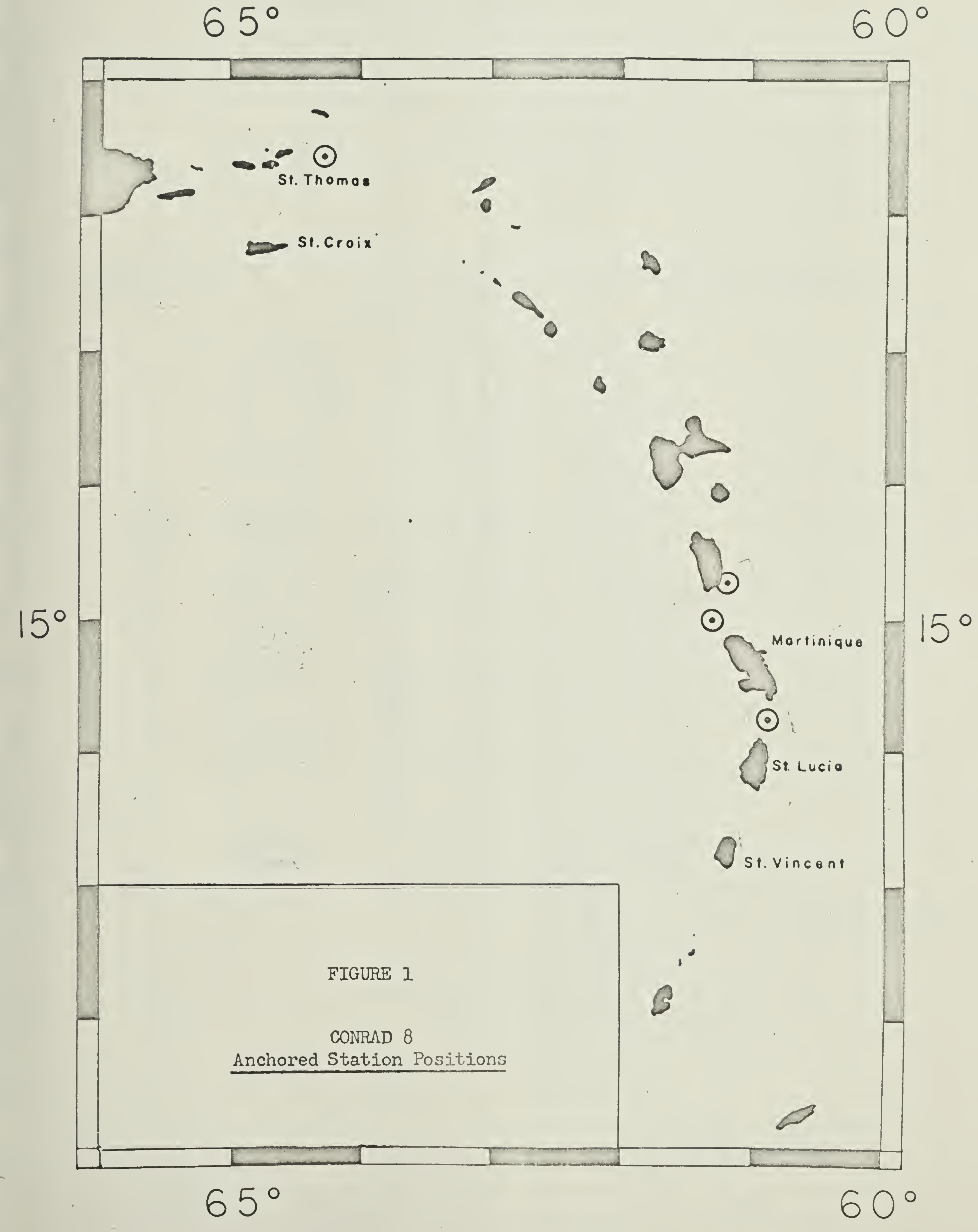
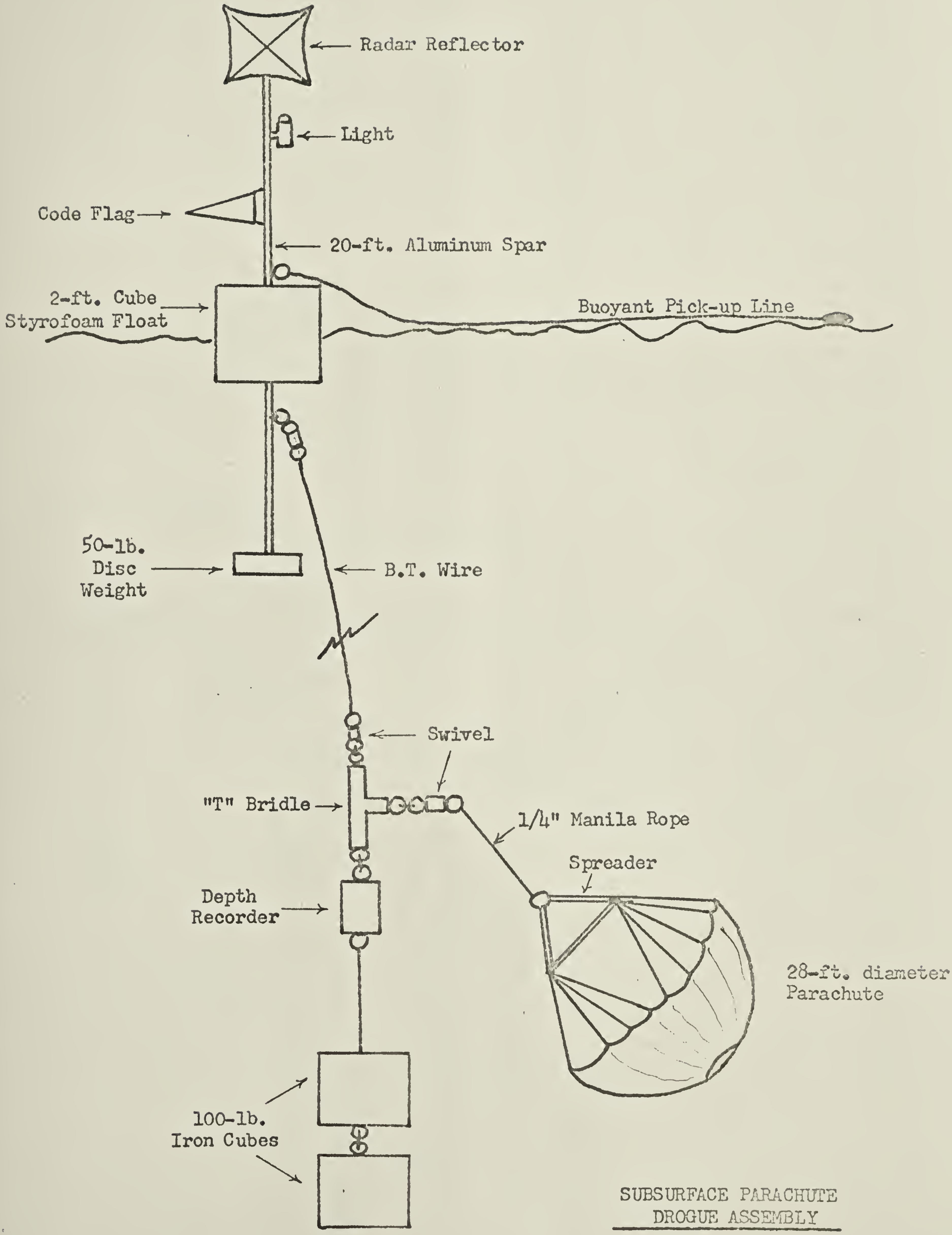


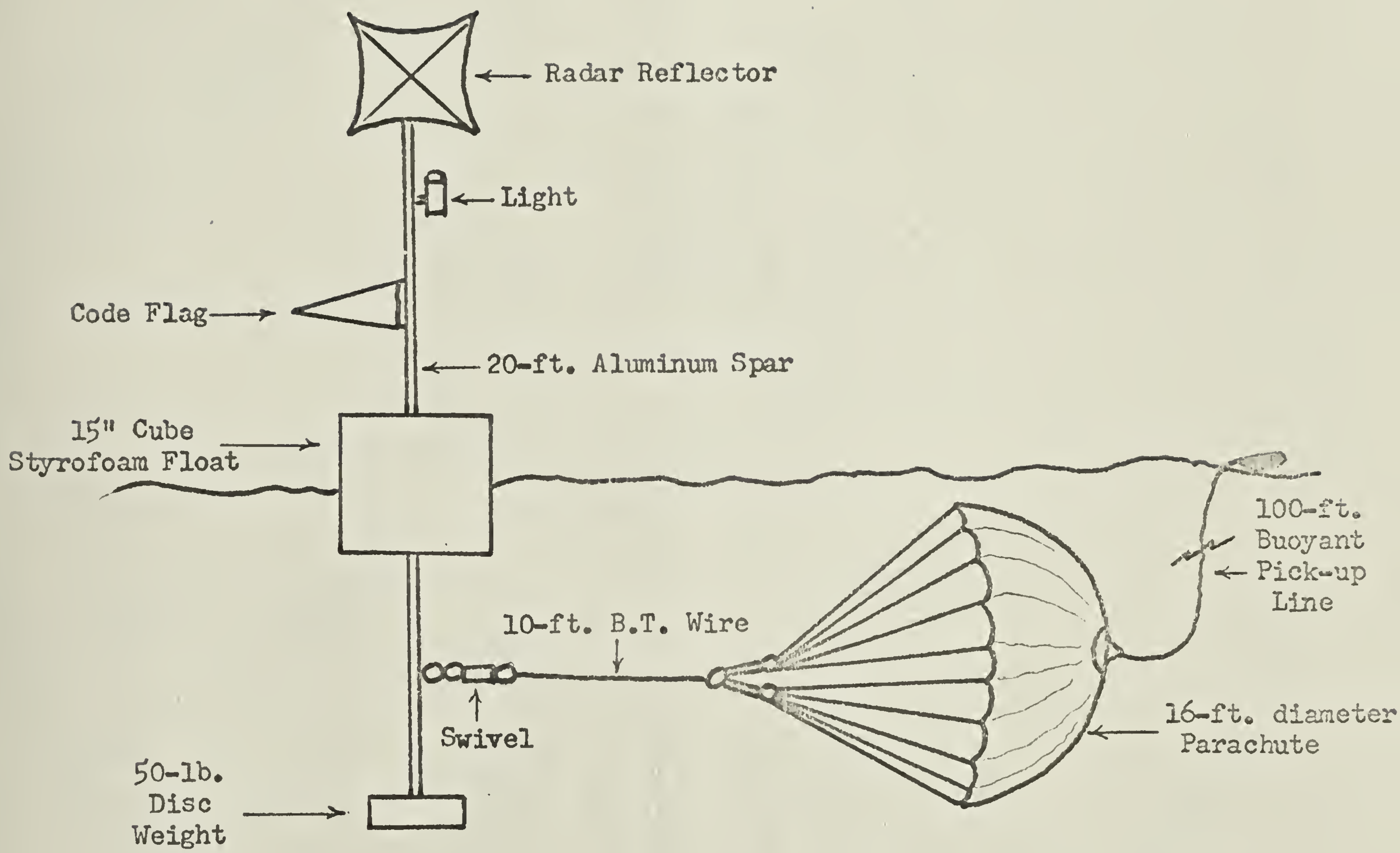
FIGURE 1

CONRAD 8
Anchored Station Positions



SUBSURFACE PARACHUTE
DROGUE ASSEMBLY

FIGURE 2



SURFACE PARACHUTE DROGUE ASSEMBLY

FIGURE 3

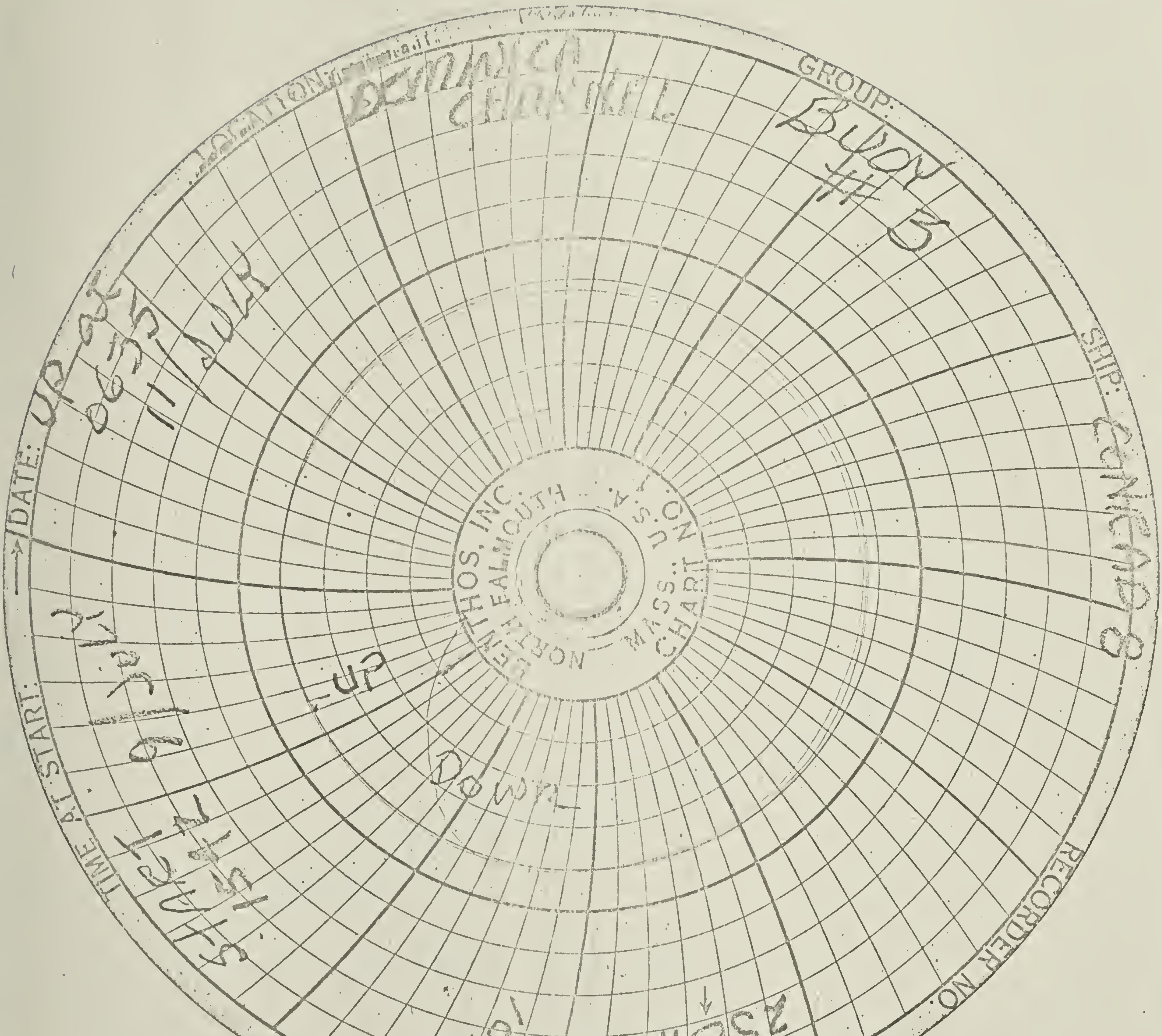
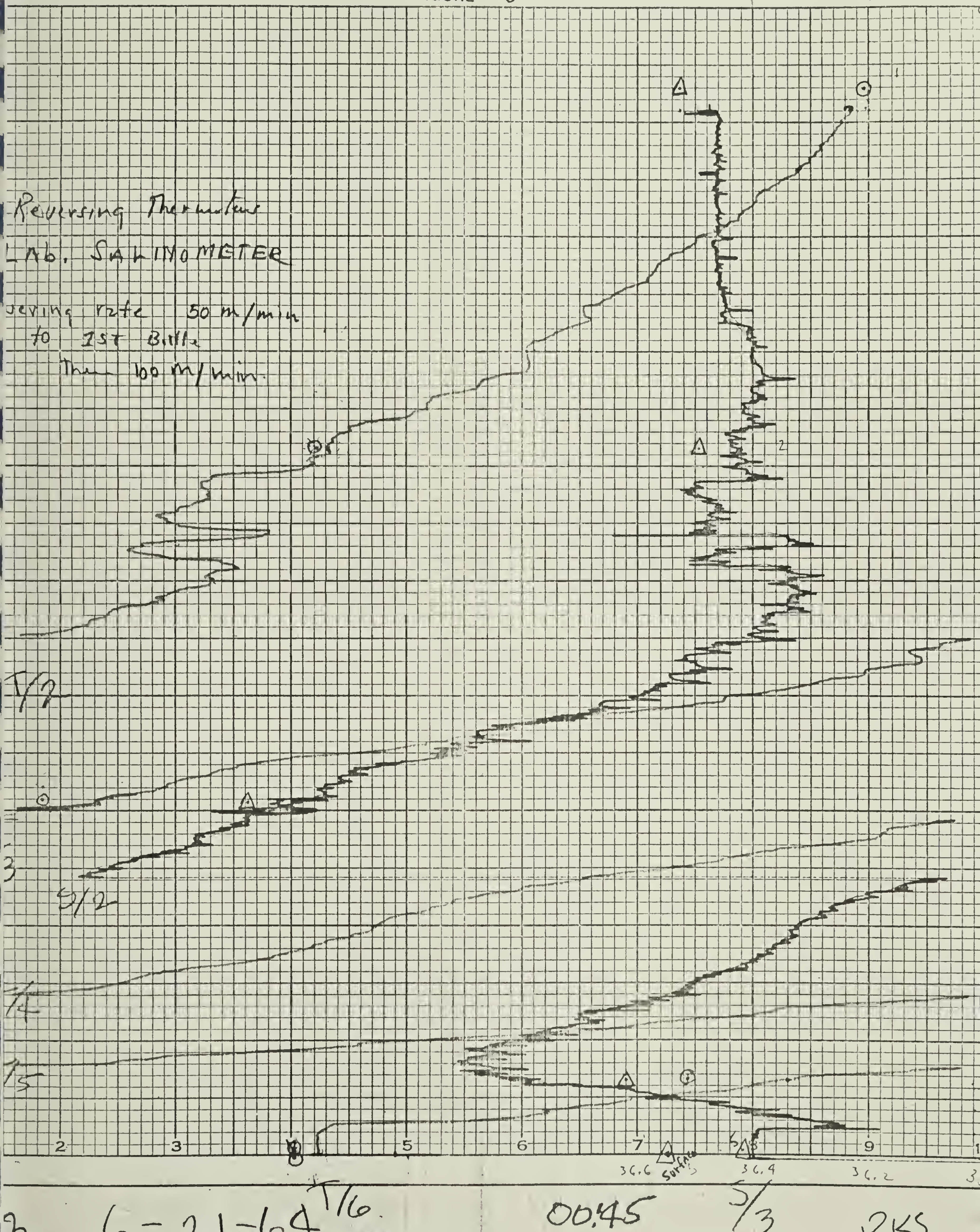

LOCATION:
GROUP:
SHIP:
RECORDER NO.
CALIBRATION
TIME AT START:
DATE:
BENTHOS, INC.
NORTH FALMOUTH
MASS. U.S.A.
CHART NO.
UP
DOWN
250 m

FIGURE 4

FIGURE 5



3 6-21-64 T/6. TEAR OFF LINE 00.45 S/3 RKS

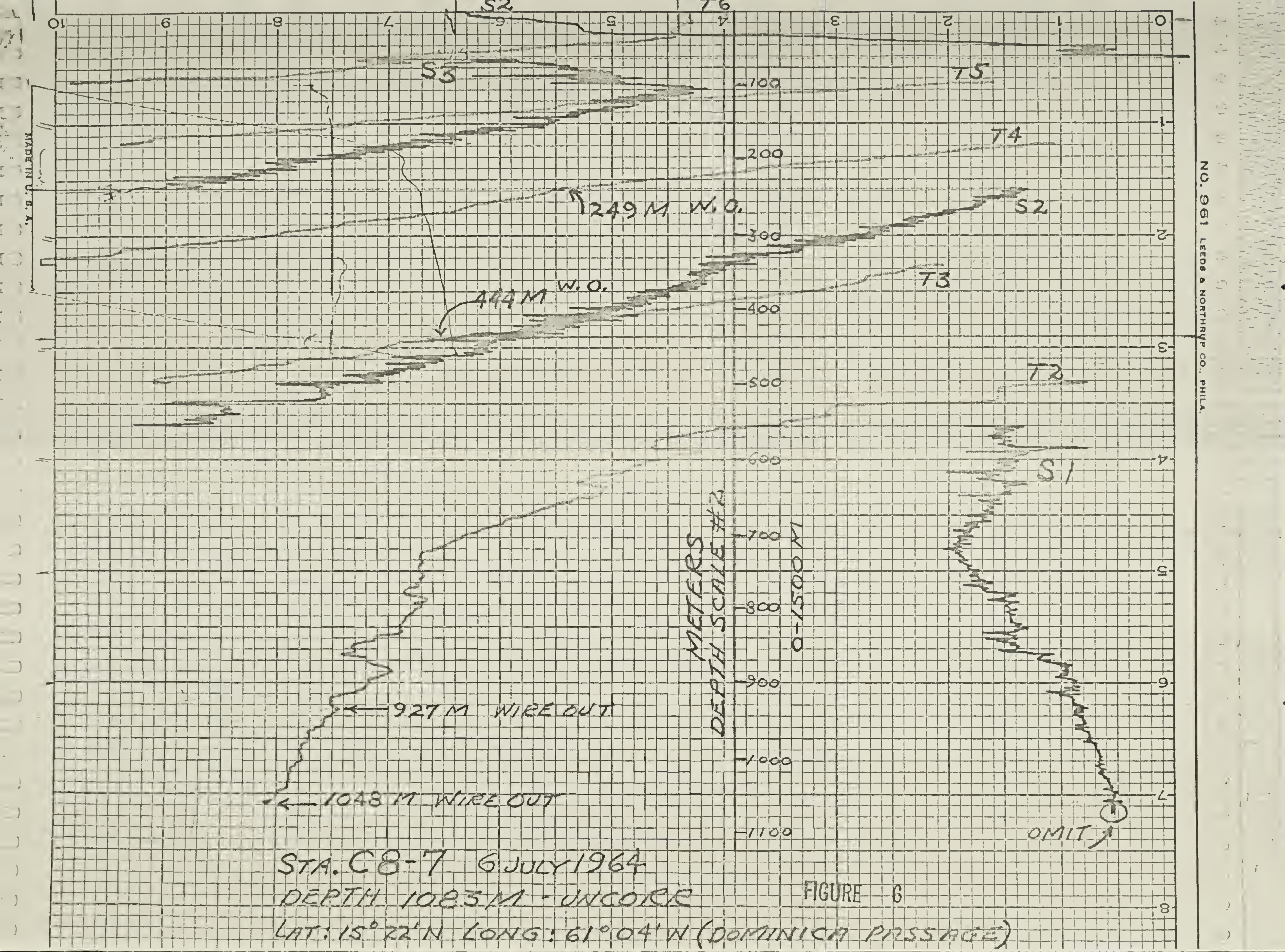
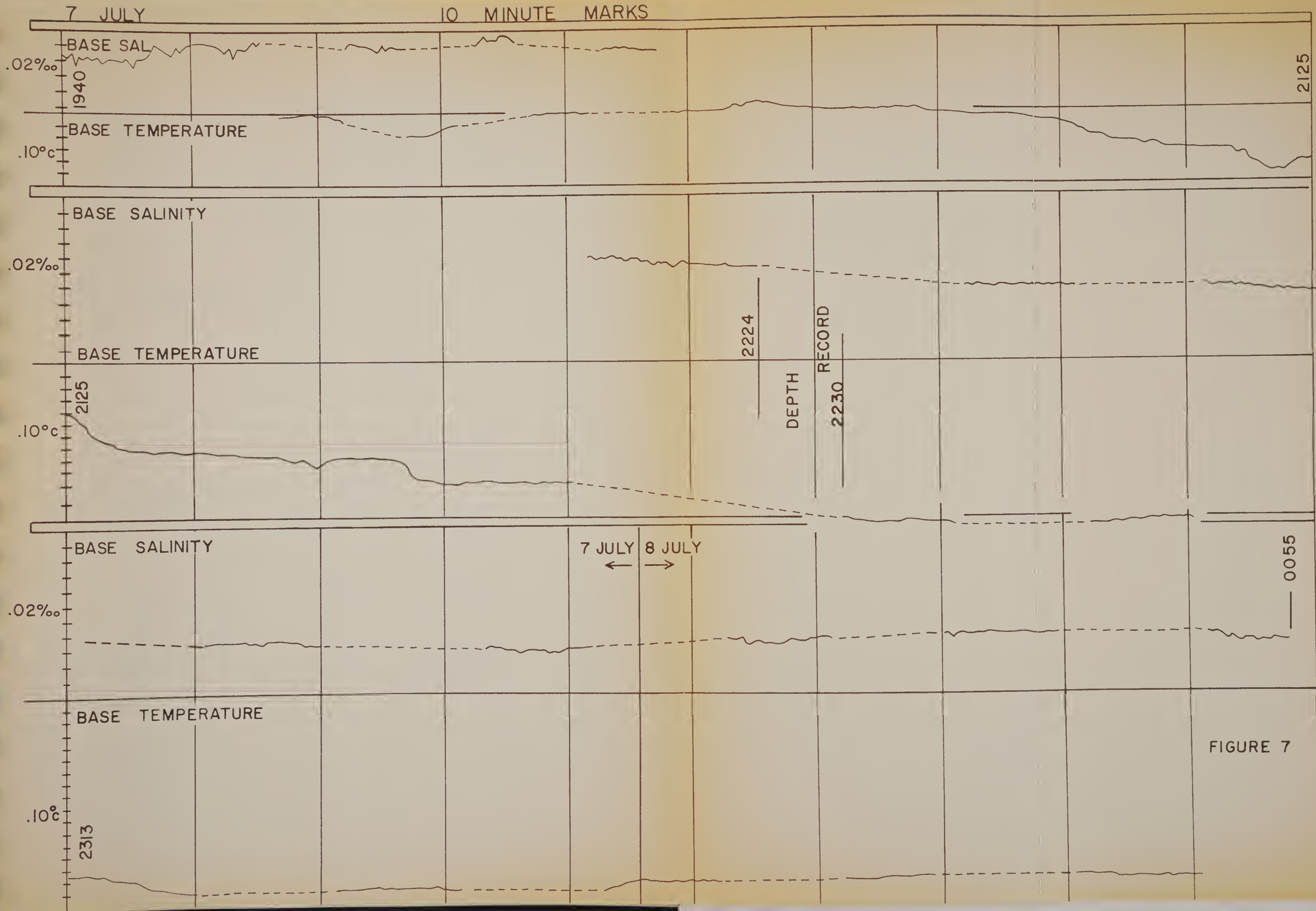

NO. 961 LEEDS & NORTHRUP CO., PHILA.
MADE IN U. S. A.
S1
S2
S3
T2
T3
T4
T5
T6
249 M W.O.
444 M W.O.
927 M WIRE OUT
1048 M WIRE OUT
OMIT
METERS
DEPTH SCALE #2
0-1500 M
STA. C8-7 6 JULY 1964
DEPTH 1083 M - UNCORE
LAT: 15° 22'N LONG: 61° 04'W (DOMINICA PASSAGE)

FIGURE 6



7 JULY
10 MINUTE MARKS
BASE SAL
.02‰
1940
2125
BASE TEMPERATURE
.10°c
BASE SALINITY
.02‰
2312
2224
DEPTH RECORD
2230
BASE TEMPERATURE
2125
.10°c
BASE SALINITY
7 JULY
8 JULY
0055
.02‰
BASE TEMPERATURE
.10°c
2313

FIGURE 7

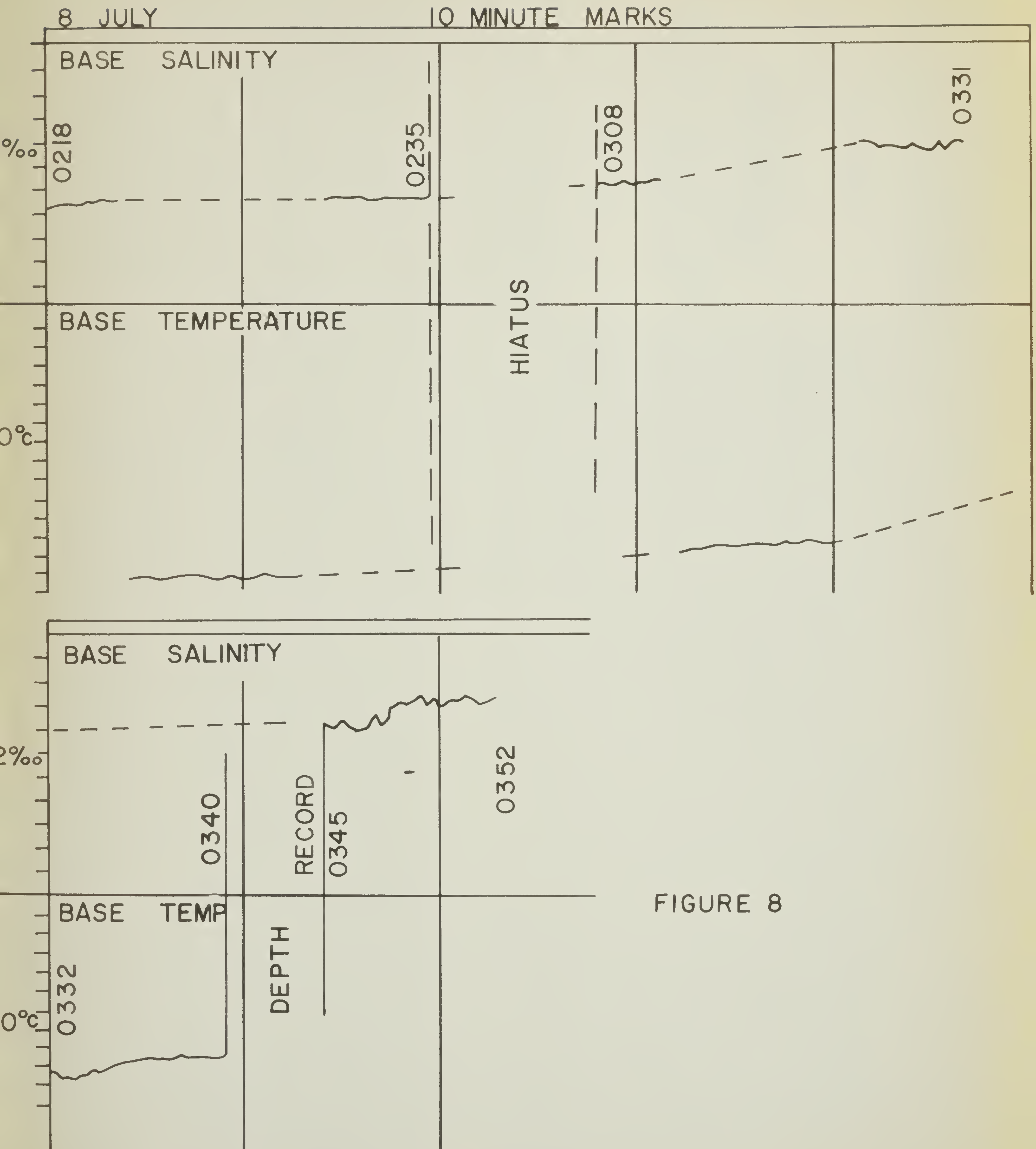
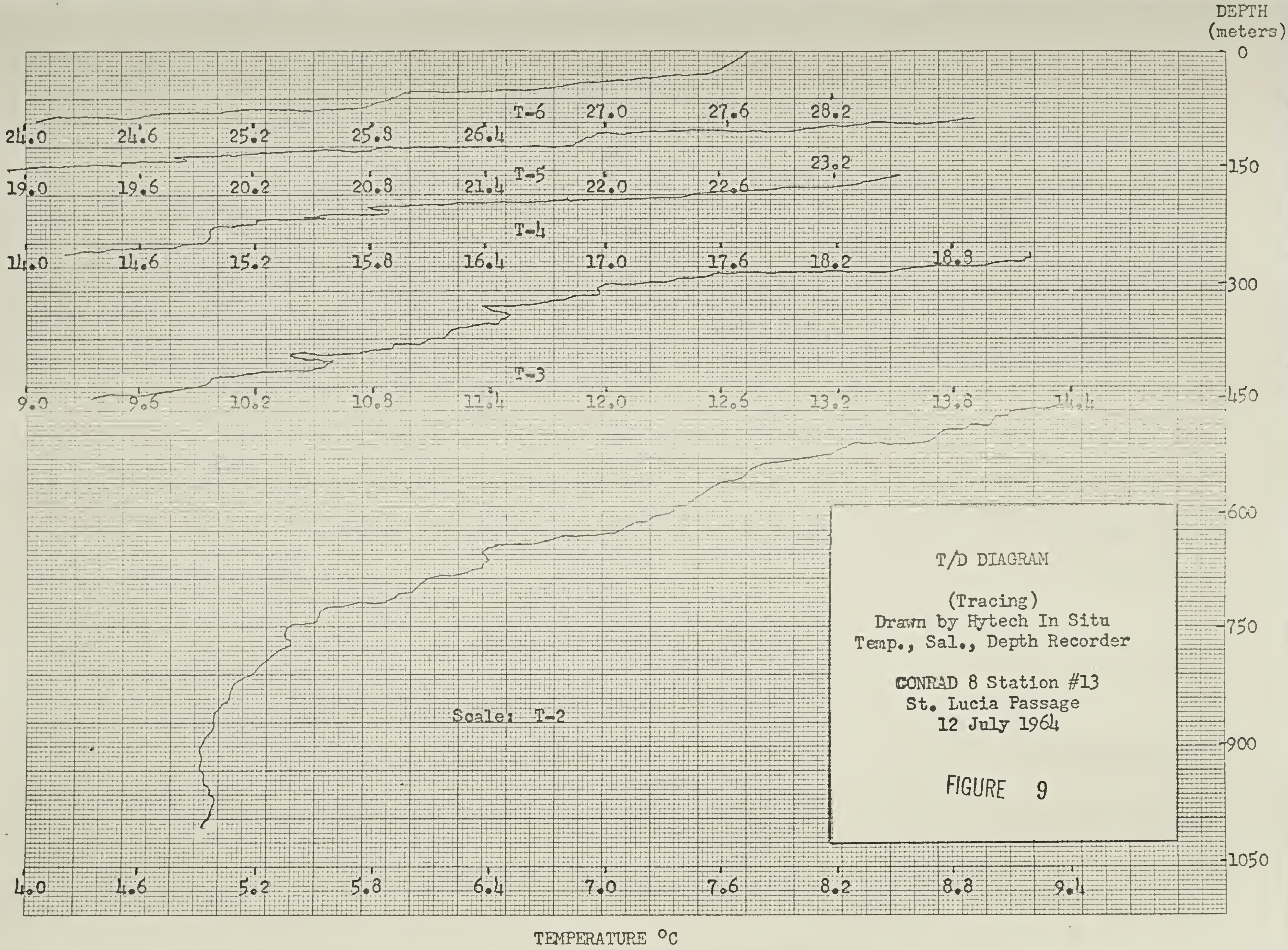

8 JULY
10 MINUTE MARKS
BASE SALINITY
0218
0235
0308
0331
HIATUS
BASE TEMPERATURE
BASE SALINITY
0340
RECORD
0345
0352
BASE TEMP
DEPTH
0332

FIGURE 8

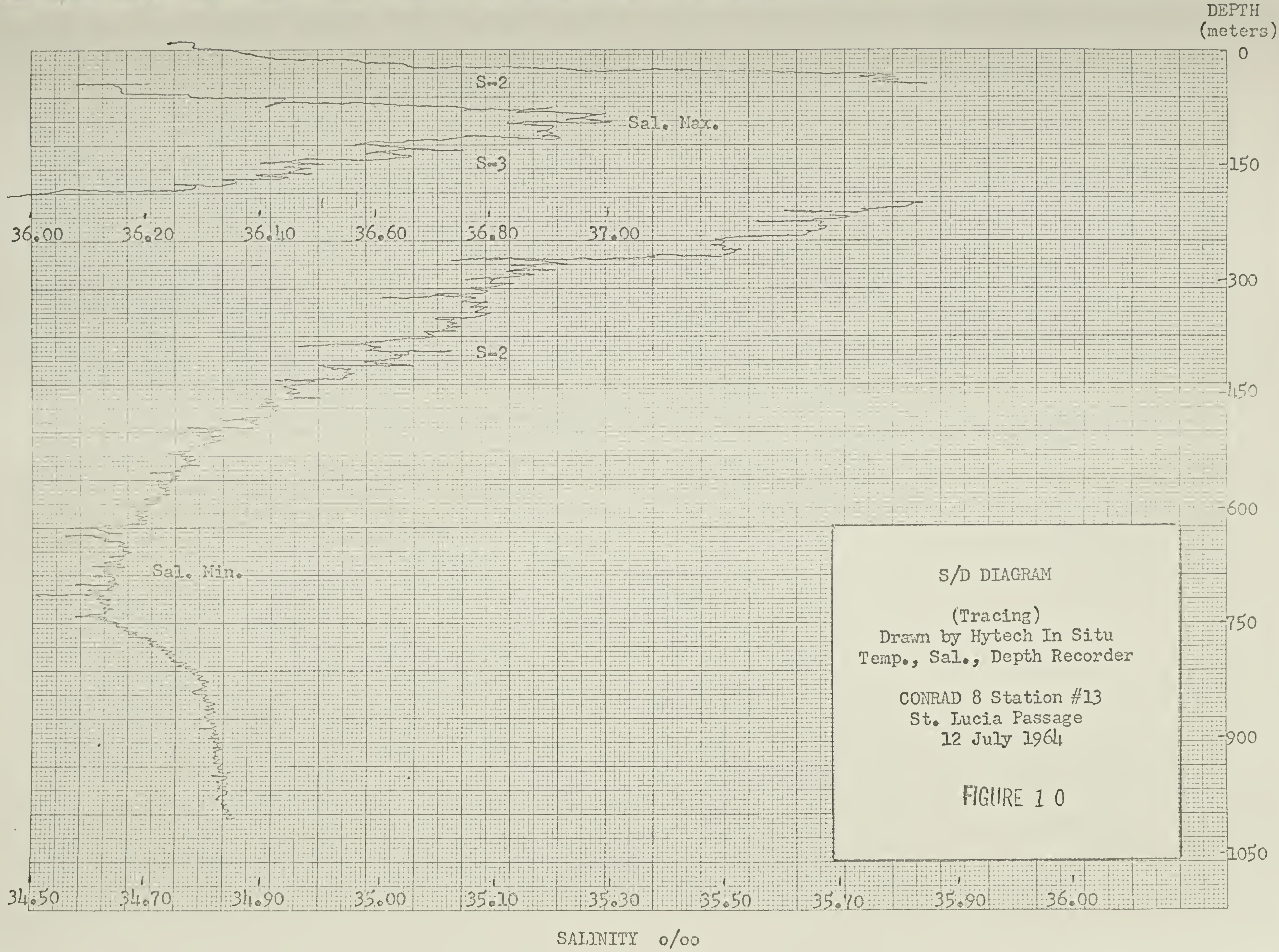


T/D DIAGRAM

(Tracing)
Drawn by Hytech In Situ
Temp., Sal., Depth Recorder

CONRAD 8 Station #13
St. Lucia Passage
12 July 1964

FIGURE 9



S/D DIAGRAM

(Tracing)
Drawn by Hytech In Situ
Temp., Sal., Depth Recorder

CONRAD 8 Station #13
St. Lucia Passage
12 July 1964

FIGURE 1 0

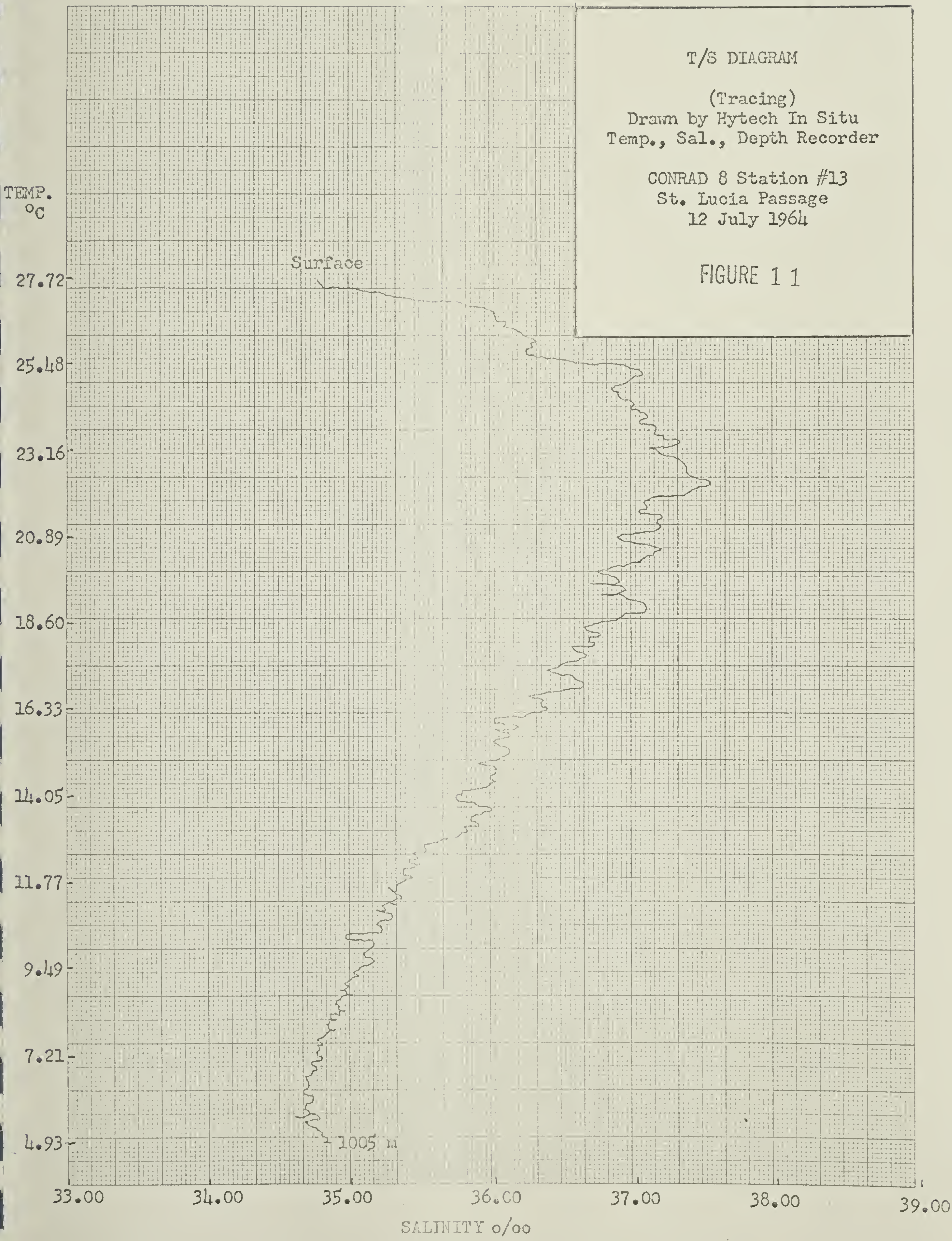
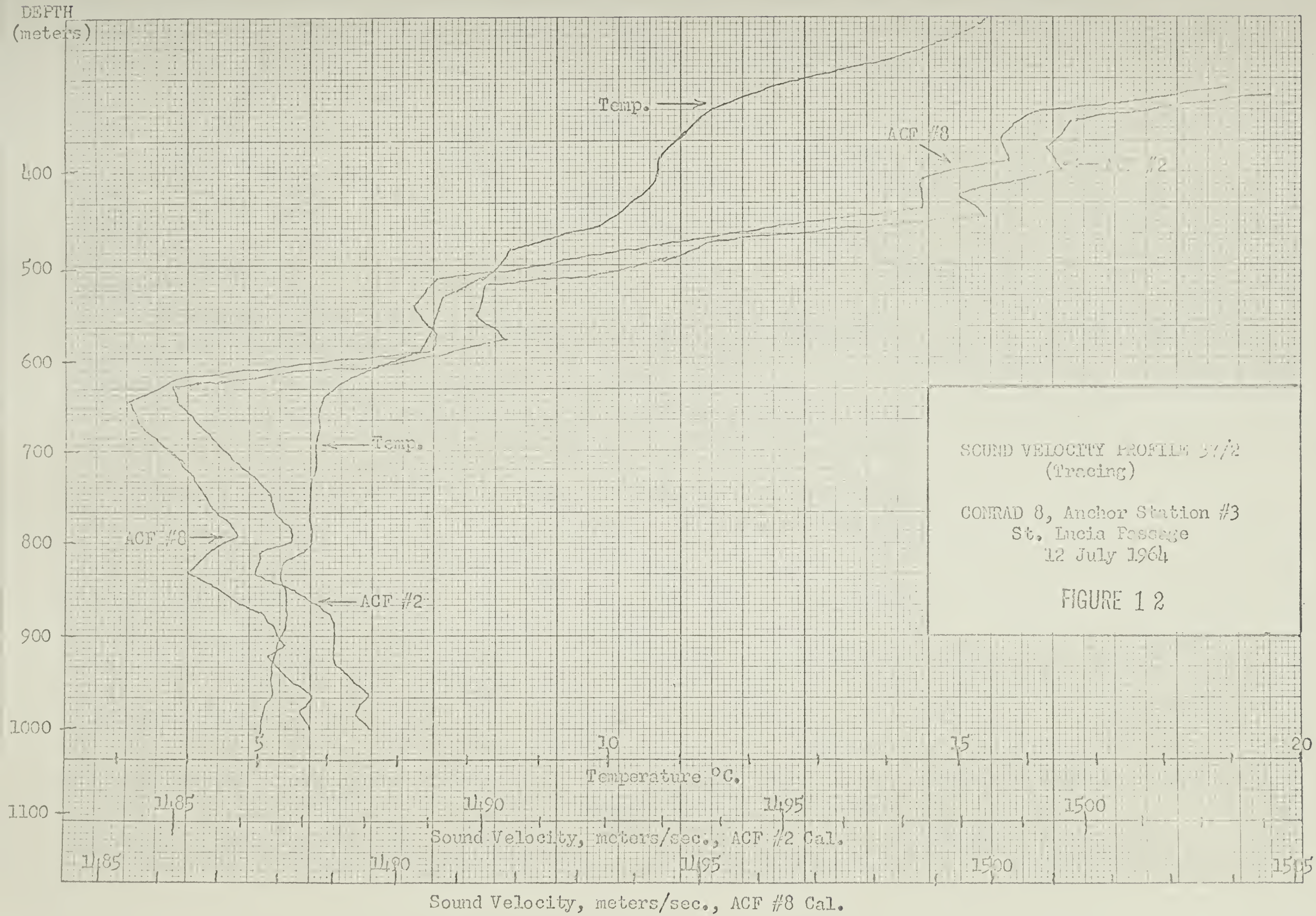

T/S DIAGRAM
(Tracing)
Drawn by Hytech In Situ
Temp., Sal., Depth Recorder
CONRAD 8 Station #13
St. Lucia Passage
12 July 1964
TEMP.
°C
Surface
27.72
25.48
23.16
20.89
18.60
16.33
14.05
11.77
9.49
7.21
4.93
1005 m
33.00
34.00
35.00
36.00
37.00
38.00
39.00
SALINITY o/oo

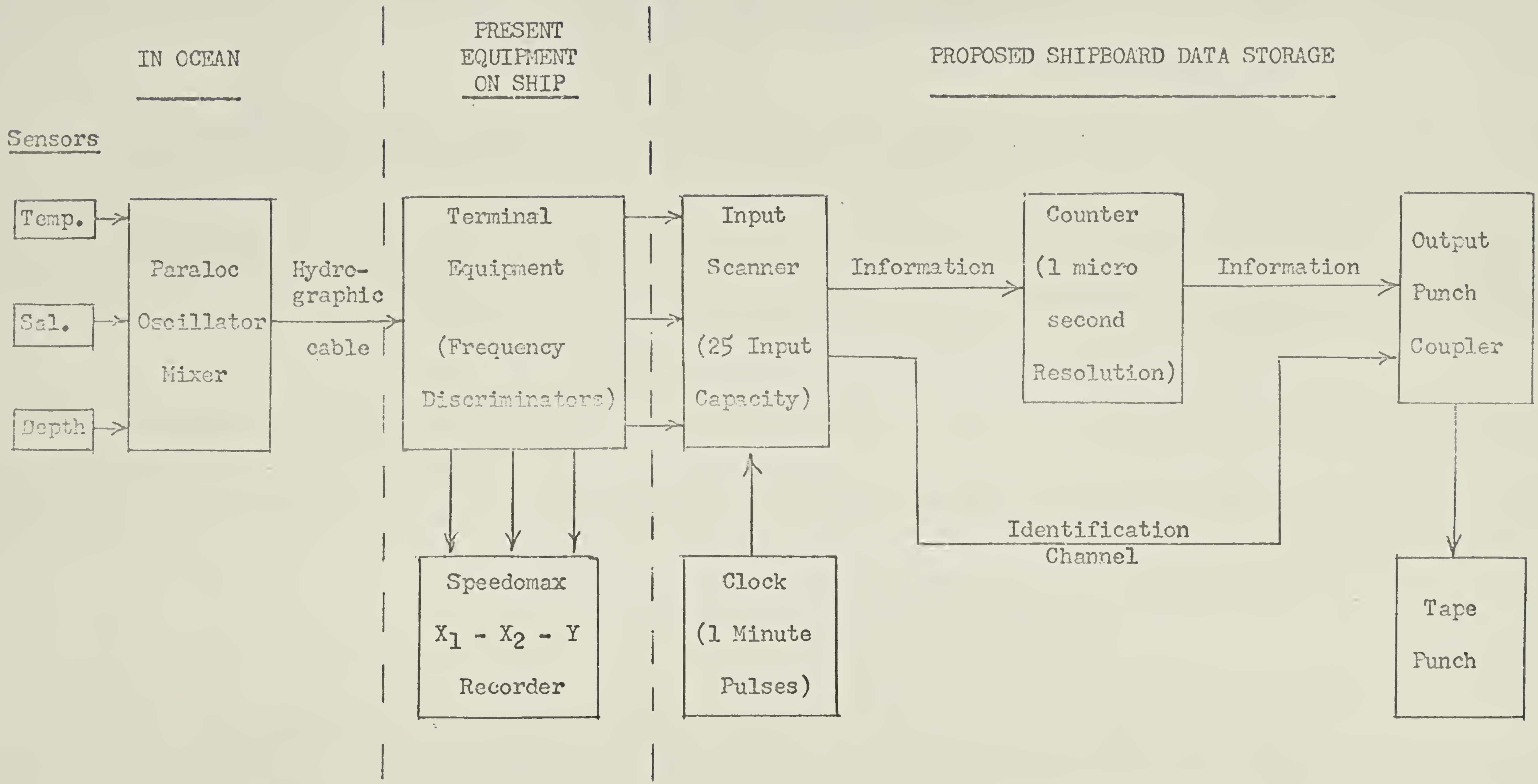
FIGURE 11



SOUND VELOCITY PROFILE 37/2
(Tracing)

CONRAD 8, Anchor Station #3
St. Lucia Passage
12 July 1964

FIGURE 1 2



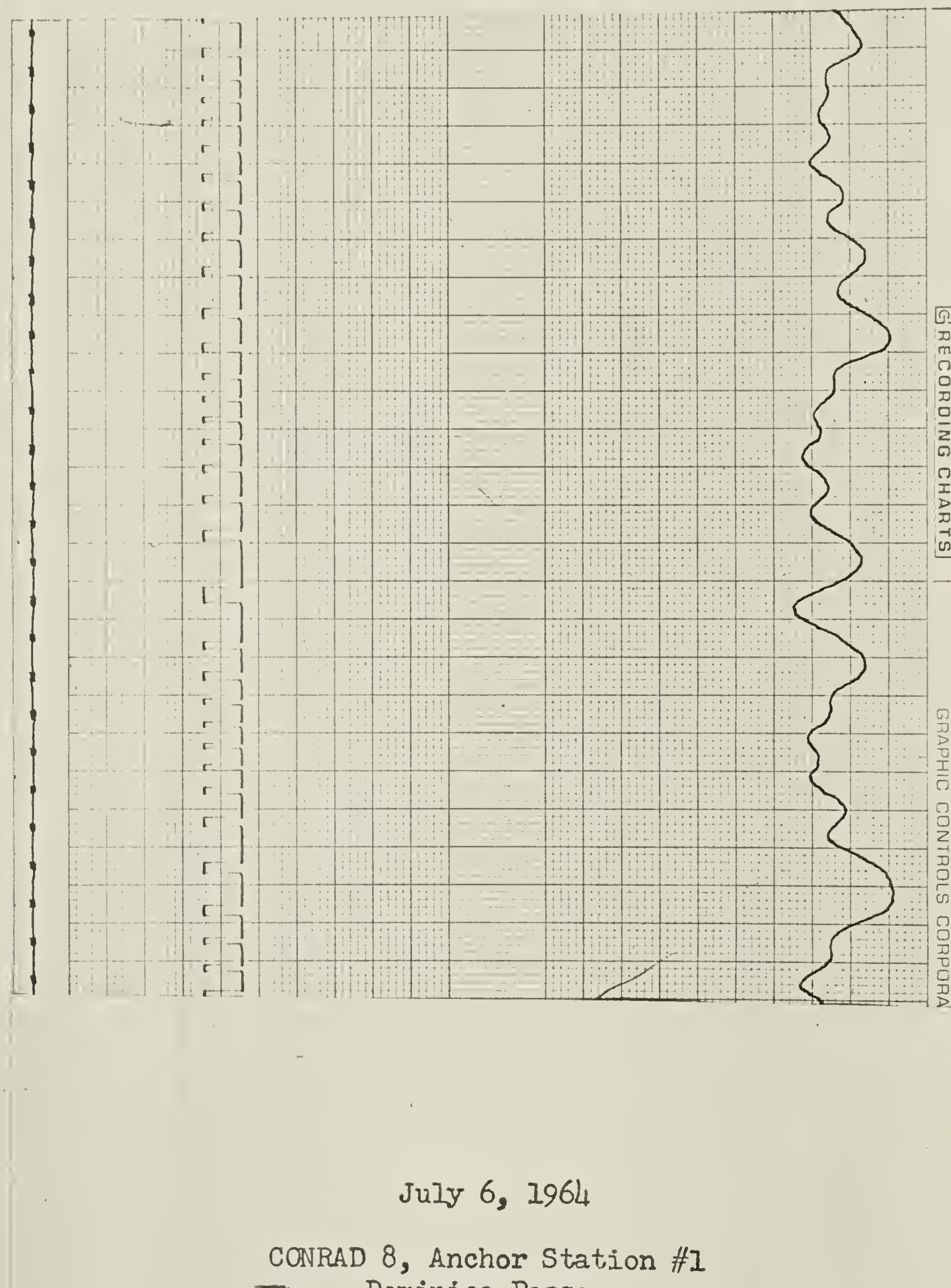
IN OCEAN
PRESENT EQUIPMENT ON SHIP
PROPOSED SHIPBOARD DATA STORAGE
Sensors
Temp.
Sal.
Depth
Paraloc Oscillator Mixer
Hydro-graphic cable
Terminal Equipment (Frequency Discriminators)
Speedomax $X_1 - X_2 - Y$ Recorder
Input Scanner (25 Input Capacity)
Clock (1 Minute Pulses)
Information
Counter (1 micro second Resolution)
Information
Output Punch Coupler
Identification Channel
Tape Punch

FIGURE 13

Deck Lowered Current Meter

showing lead weight in foreground
and electrical swivel above

FIGURE 1 4

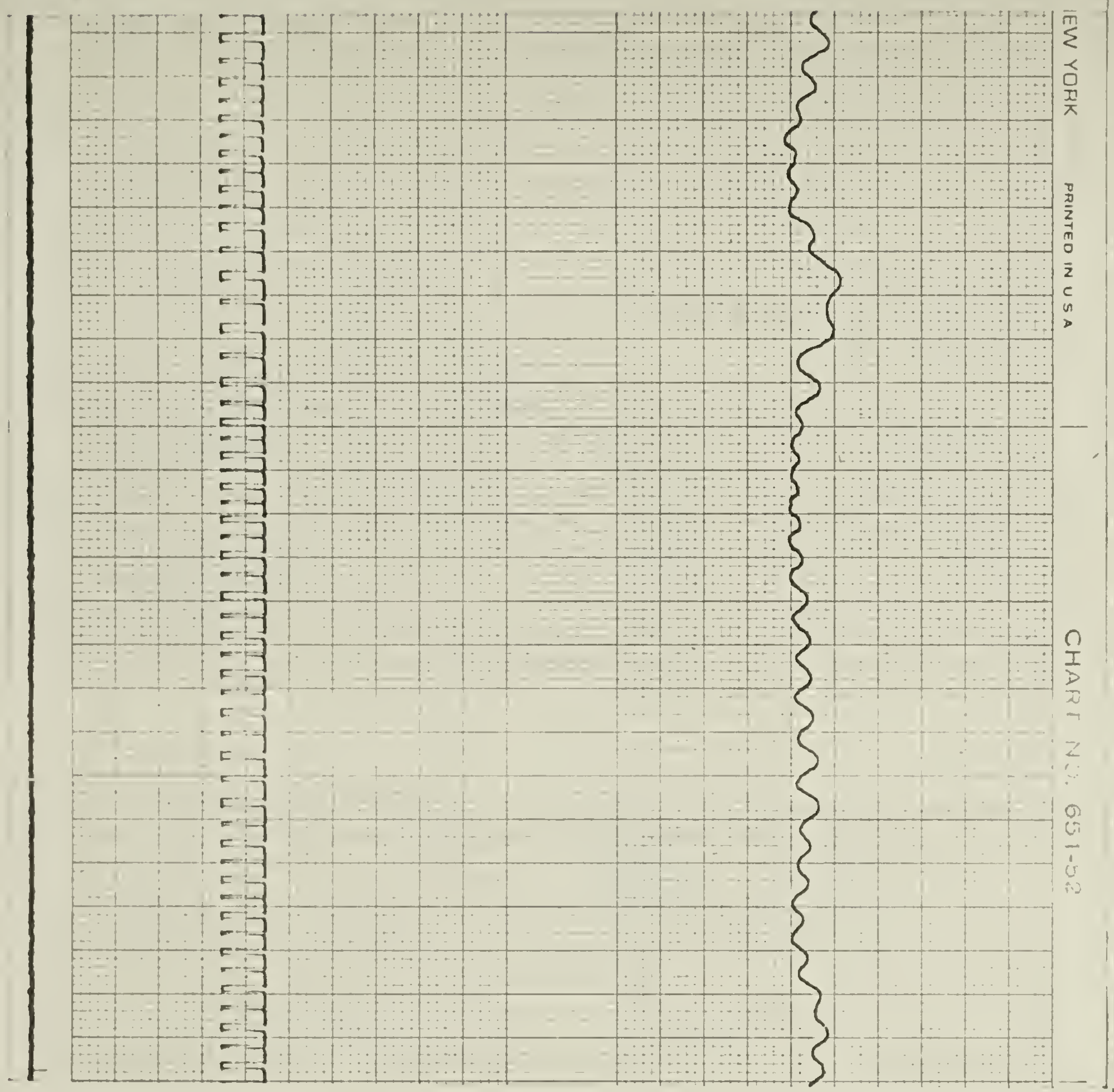


July 6, 1964

CONRAD 8, Anchor Station #1
Dominica Passage

Segment of Surface Current Meter Record

FIGURE 1 5

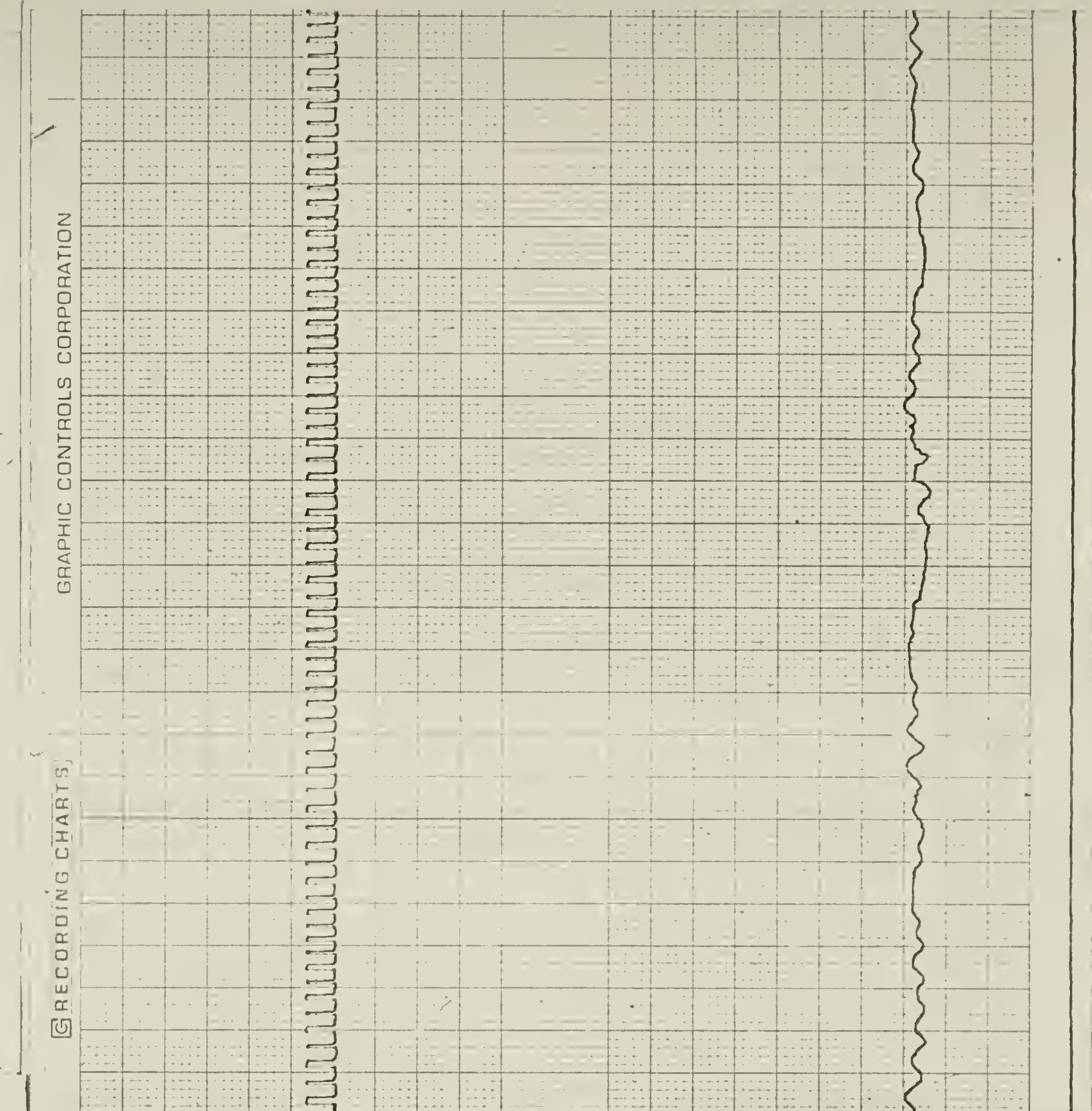


July 9, 1964

CONRAD 8, Anchor Station #2
Dominica Passage

Segment of Surface Current Meter Record

FIGURE 16



July 12, 1964

CONRAD 8, Anchor Station #3
St. Lucia Passage

Segment of Surface Current Meter Record

FIGURE 17

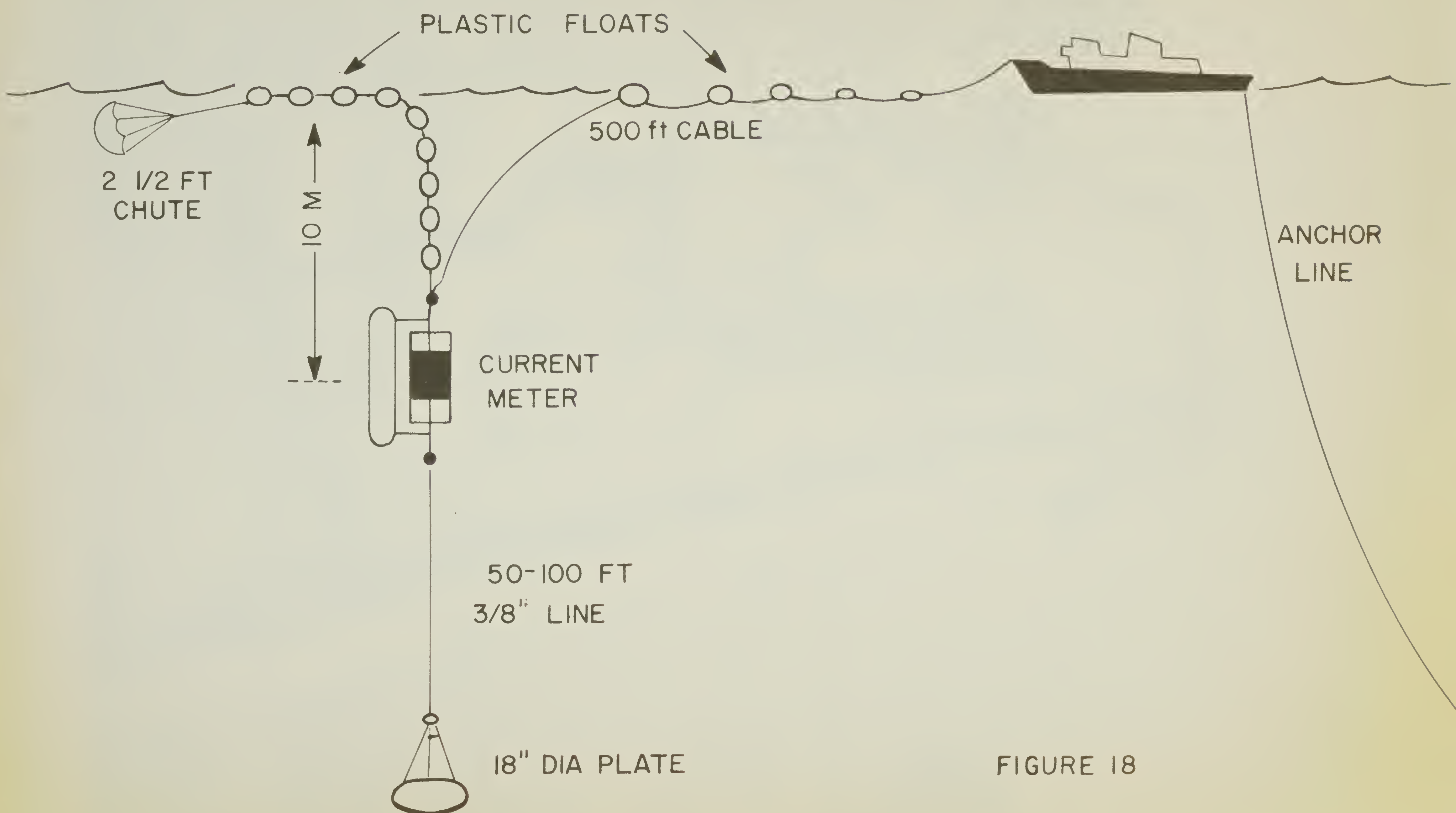

PLASTIC FLOATS
500 ft CABLE
2 1/2 FT
CHUTE
10 M
CURRENT
METER
ANCHOR
LINE
50-100 FT
3/8" LINE
18" DIA PLATE

FIGURE 18

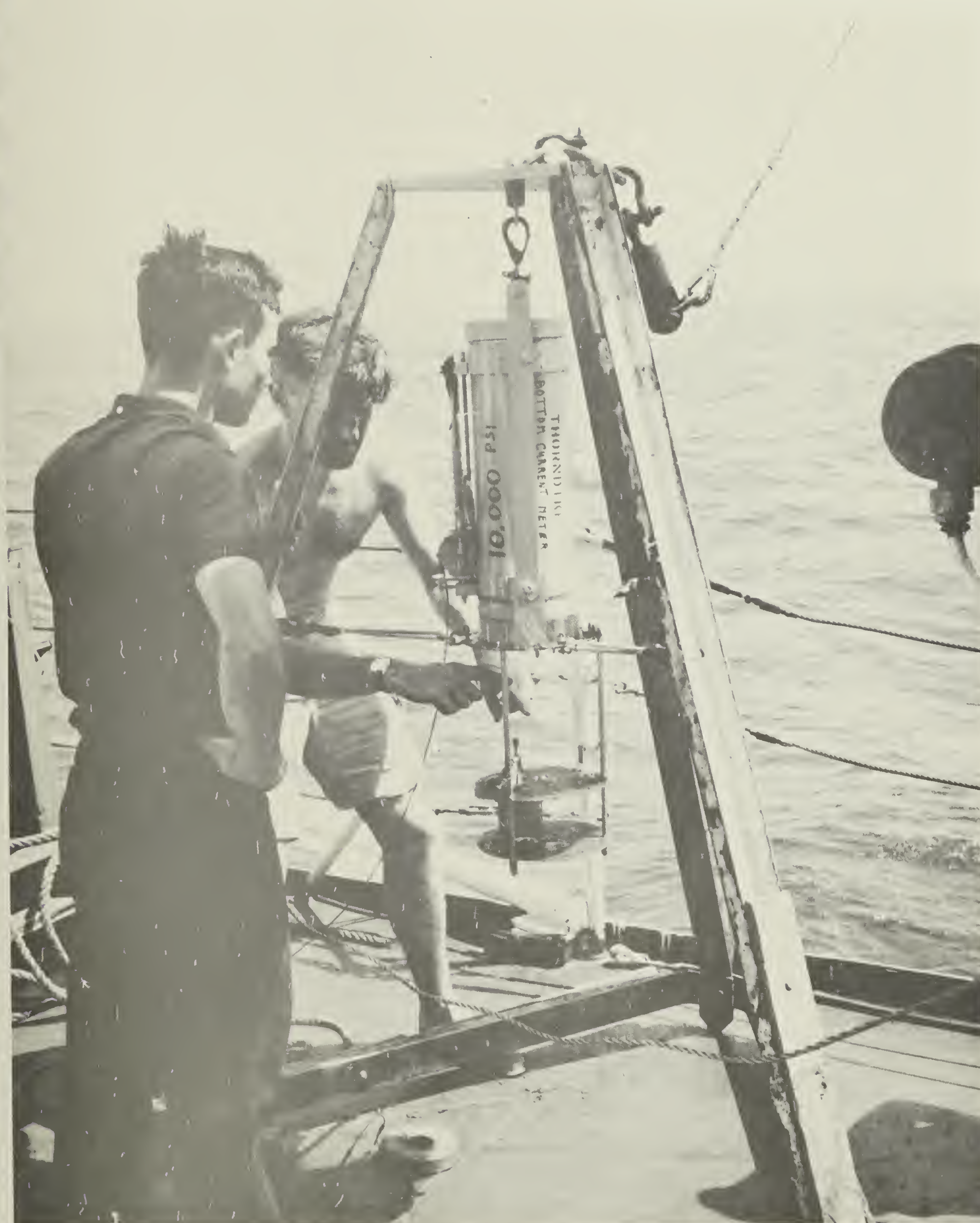
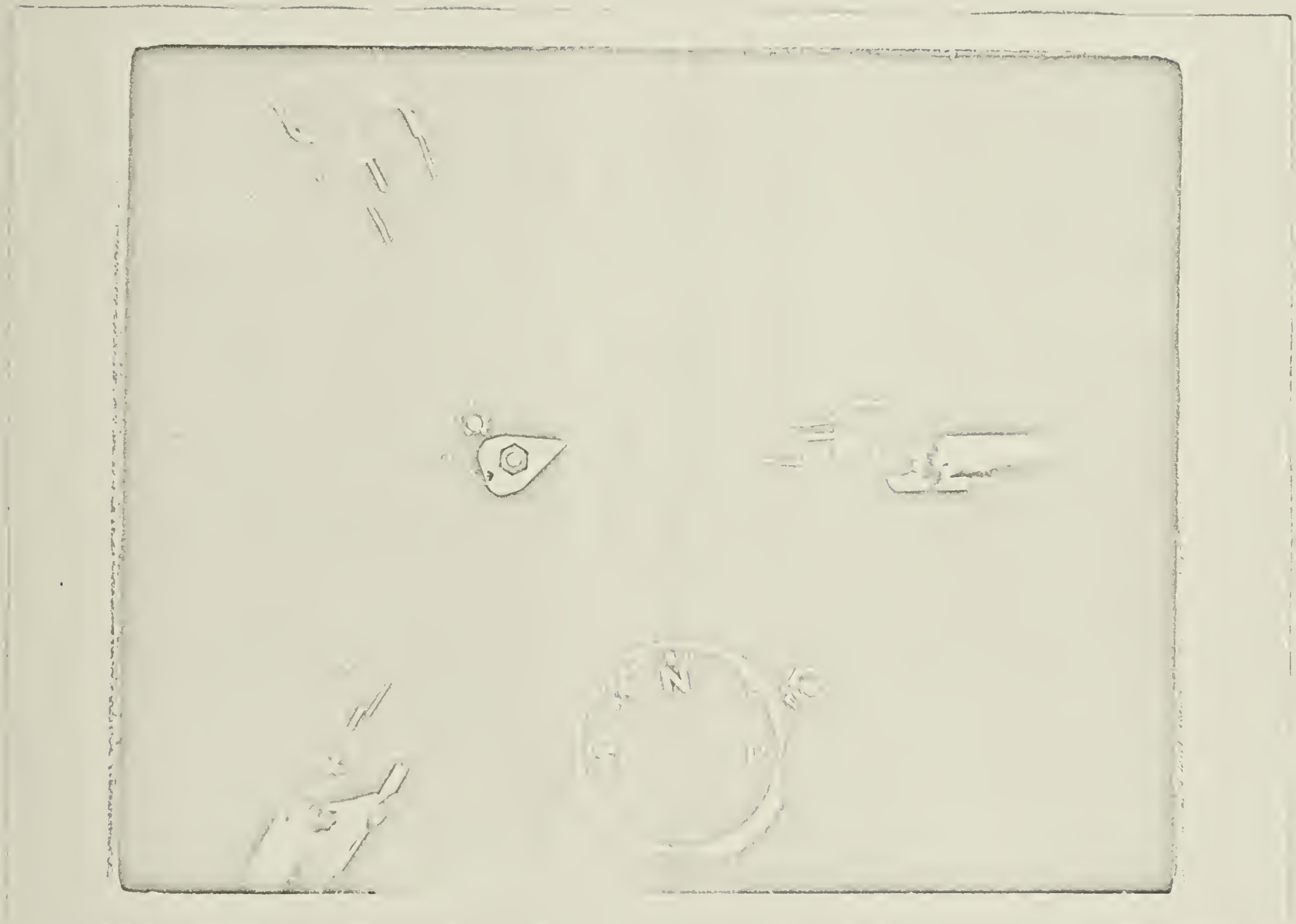


FIGURE 19



Enlarged 35mm. Frame
from the
Thorndike Bottom Camera Current Meter

FIGURE 20

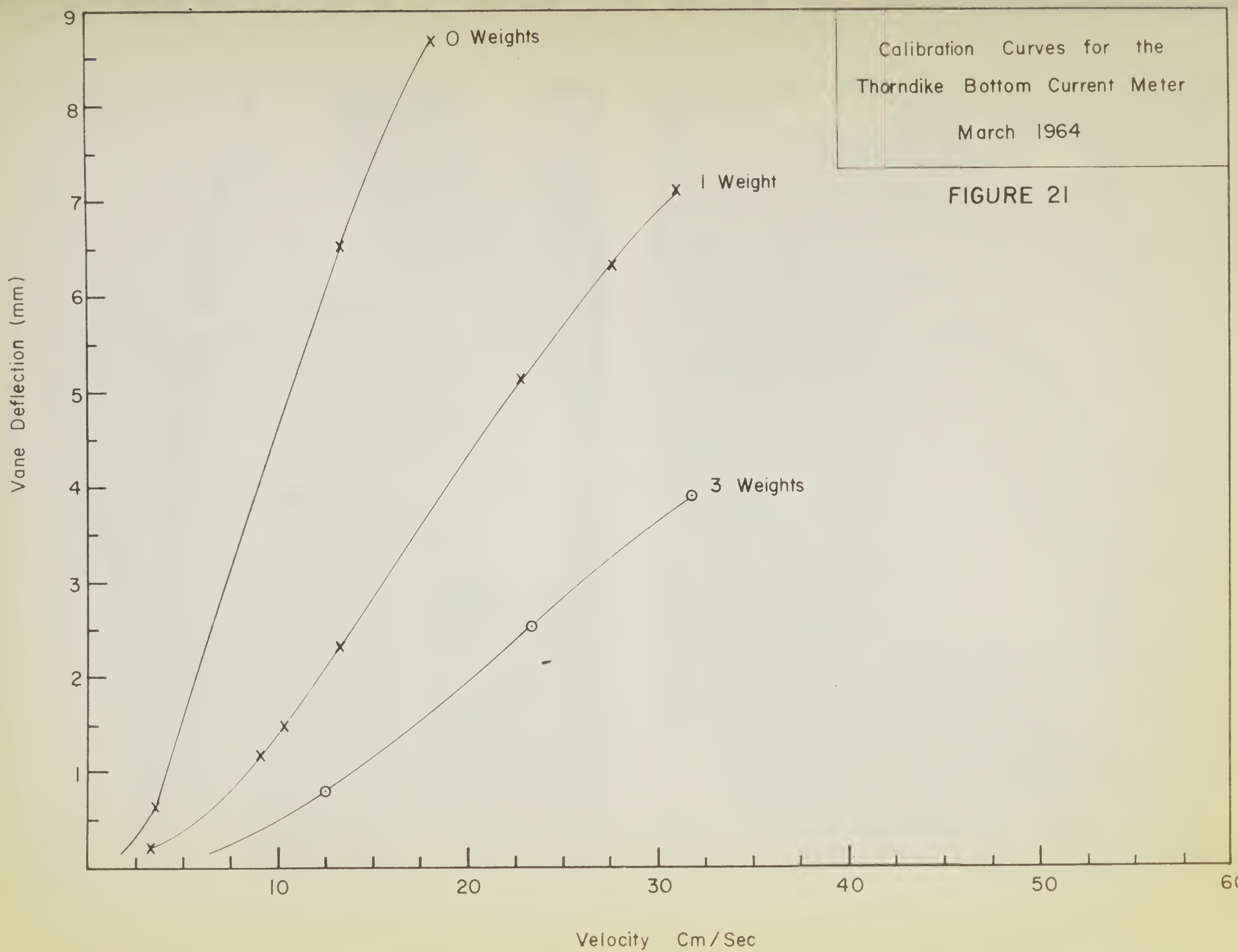

Calibration Curves for the
Thorndike Bottom Current Meter
March 1964
0 Weights
1 Weight
3 Weights
Vane Deflection (mm)
Velocity Cm/Sec
1
2
3
4
5
6
7
8
9
10
20
30
40
50
60

FIGURE 21

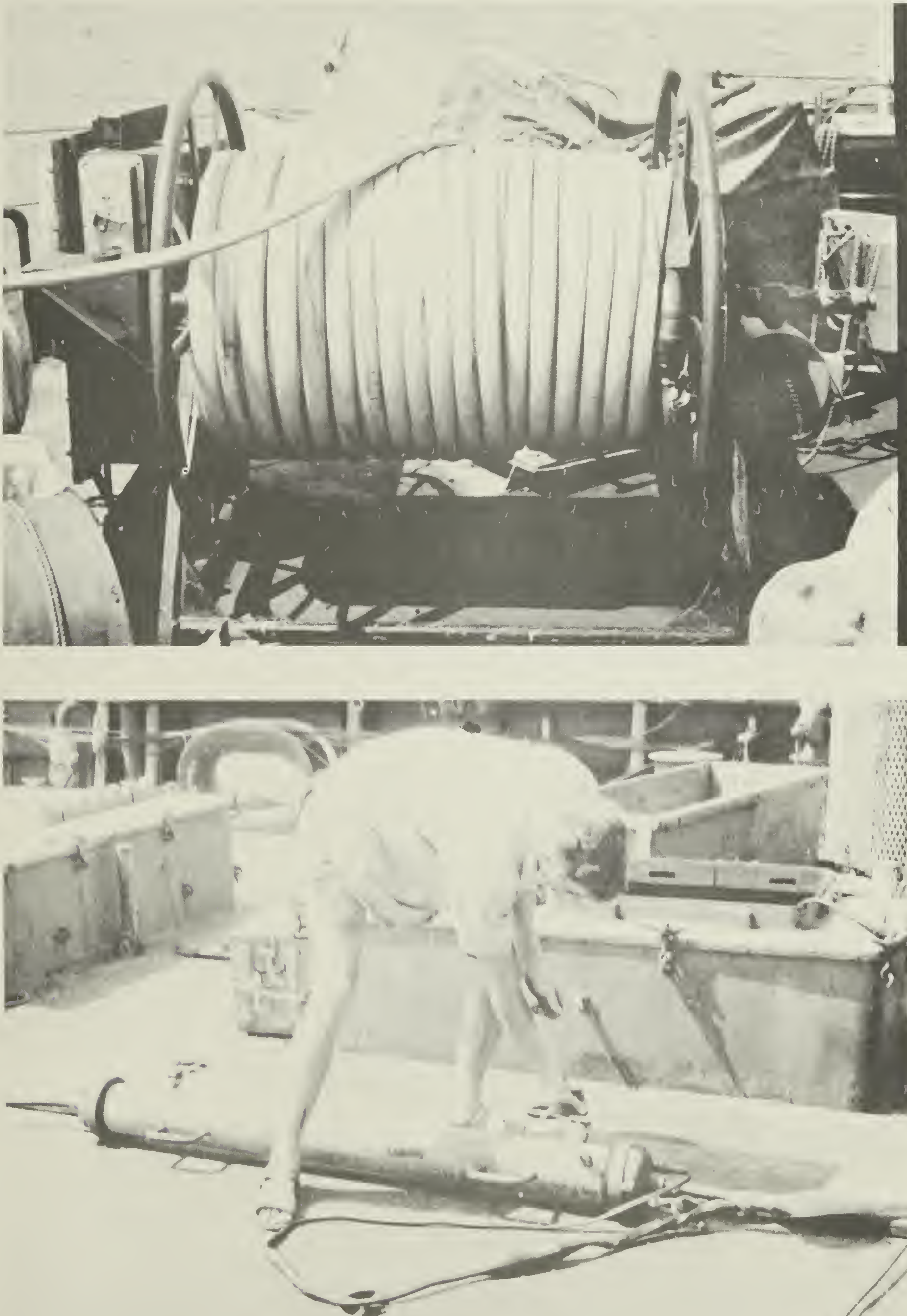


FIGURE 2 2

REFERENCE

Volkmann, G., Knauss, J. and Vine, A., 1956. The use of parachute drogues in the measurement of subsurface ocean currents: Transactions, American Geophysical Union, 37 (5), 573-577.

ACKNOWLEDGMENTS

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